# Getting started with WAsP 8

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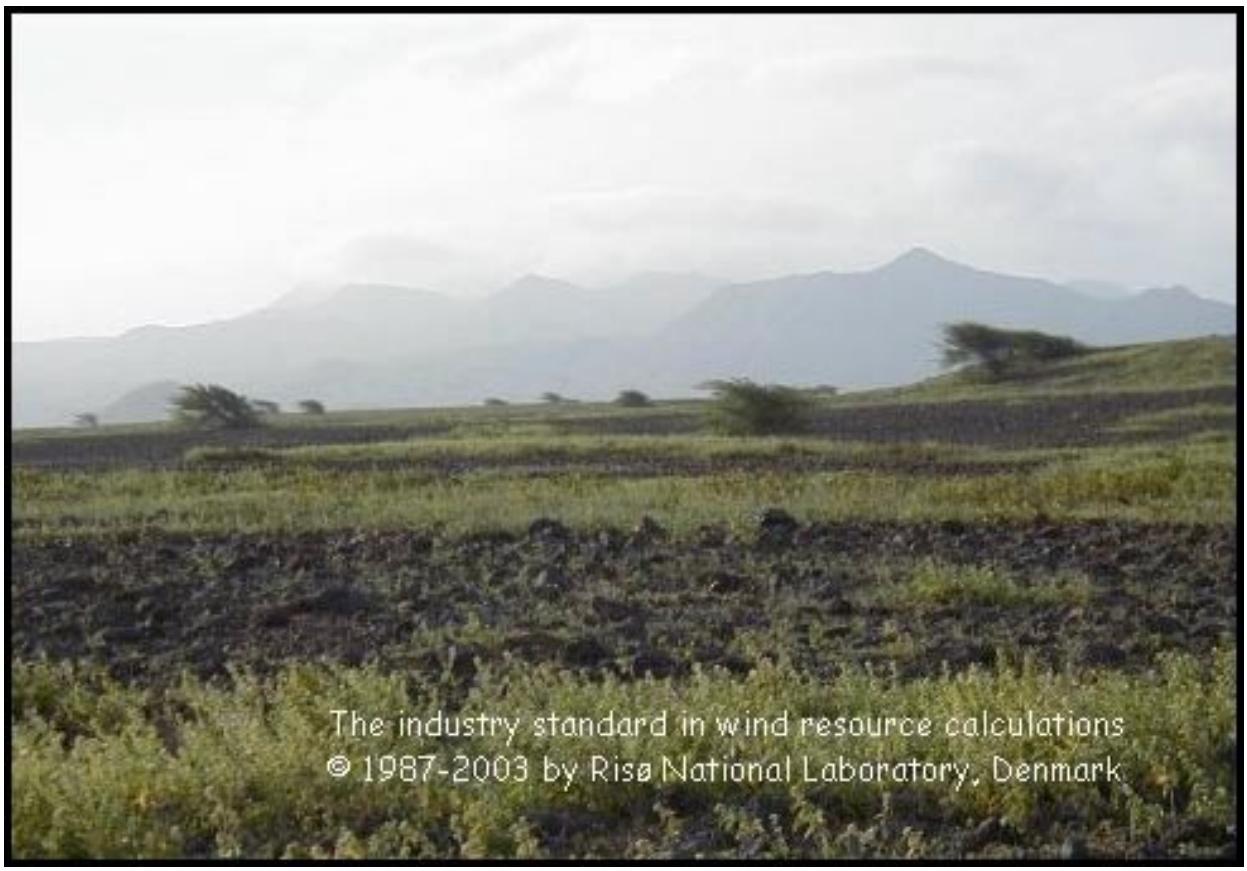


**Risø National Laboratory, Roskilde, Denmark**
**January 2003**

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**Risø National Laboratory, Roskilde**
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**Abstract** The Wind Atlas Analysis and Application Program (WAsP) is a PC-program for horizontal and vertical extrapolation of wind data. The program contains a complete set of models to calculate the effects on the wind of sheltering obstacles, surface roughness changes and terrain height variations. The analysis part consists of a transformation of an observed wind climate (speed and direction distributions) to a wind atlas data set. The wind atlas data set can subsequently be applied for estimation of the wind climate and wind power potential, as well as for siting of specific wind turbines. The WAsP 8 Help Facility includes a Quick Start Tutorial, a User's Guide and a Technical Reference. It further includes descriptions of the Observed Wind Climate Wizard, the WAsP Map Editor tool, the WAsP Turbine Editor tool and the Air Density Calculator.

This report consists of excerpts from the electronic version of the WAsP 8 help facility:

Mortensen, N.G., D.N. Heathfield, L. Myllerup, L. Landberg, O. Rathmann, I. Troen and E.L. Petersen (2003). Wind Atlas Analysis and Application Program: WAsP 8 Help Facility. Risø National Laboratory, Roskilde, Denmark. 309 topics. ISBN 87-550-3171-4.

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# 1 Introduction

## 1.1 Welcome

In 1987 the Wind Energy and Atmospheric Physics Department at Risø National Laboratory introduced WAsP – a powerful tool for wind data analysis, wind atlas generation, wind climate estimation and siting of wind turbines. Over the years, the program has become the industry standard for wind resource assessment and siting of wind turbines and wind farms and it has been employed in more than 90 countries all over the world.

A new release of this indispensable tool for everybody working with wind energy is now available – WAsP 8 for Windows 98, Me, NT 4, 2000 and XP. The program has been developed by the same team who worked out the Danish Windatlas, the European Wind Atlas and previous versions of the WAsP programs.

The algorithms at the heart of the WAsP software have been tested and applied for more than 15 years in many different parts of the world. As time has passed, most of our efforts have been devoted to refining the WAsP algorithms and supporting the existing software. Meanwhile, user interface design standards have moved on. Many users (and prospective users) have indicated their desire for a new, modern, user interface. WAsP for Windows is intended to meet these demands.

WAsP is 100% 32-bit Windows software, which runs under Windows 98, Windows Me, Windows NT 4.0, Windows 2000 and Windows XP. It conforms to standard windows software user-interface conventions, making it easy to learn and easy to use.

We recommend that you work through the Quick Start Tutorial – to see for yourself what WAsP 8 is all about. If you're already familiar with the previous DOS versions of WAsP, you might read on here before entering the tutorial.

With the release of WAsP 8, we also plan to handle feedback and support in a much more systematic and dynamic way than before. The main focal point for these efforts will be the WAsP home page. Among other things, we plan to maintain a list of Frequently Asked Questions (FAQ) and a list of Known Issues. Last, but not least, there will be a Download Page where you can download the latest version of the software and help file. Users who do not have access to the Internet may receive free updates on disk.

As it says in the License Agreement and Copyright Statement, the WAsP software is provided 'as is' and 'does not represent a commitment on the part of Risø National Laboratory' etc. However, we are of course aware that the programs may contain errors, programming bugs and inconsistencies – especially with the introduction of this major upgrade. Therefore, we guarantee that we will do our best to check, maintain and correct the programs in the WAsP package, and that we'll make available or distribute corrected versions to registered users of the software.

We wish you the best of luck with your wind projects and hope WAsP 8 can help you reach your goals.

The WAsP team at Risø

## 1.2 What is WAsP?

WAsP is a PC-program for the vertical and horizontal extrapolation of wind climate statistics. It contains several models to describe the wind flow over different terrains and close to sheltering obstacles. WAsP consists of five main calculation blocks:

**Analysis of raw data**. This option enables an analysis of any time-series of wind measurements to provide a statistical summary of the observed, site-specific wind climate. This part is implemented in a separate tool, the Observed Wind Climate (OWC) Wizard.

**Generation of wind atlas data**. Analyzed wind data can be converted into a wind atlas data set or regional wind climate. In a wind atlas data set the wind observations have been 'cleaned' with respect to site-specific conditions. The wind atlas data sets are site-independent and the wind distributions have been reduced to some standard conditions.

**Wind climate estimation**. Using a wind atlas data set calculated by WAsP or one obtained from another source – e.g. the European Wind Atlas – the program can estimate the wind climate at any specific point by performing the inverse calculation as is used to generate a wind atlas. By introducing descriptions of the terrain around the predicted site, the models can predict the actual, expected wind climate at this site.

**Estimation of wind power potential**. The total energy content of the mean wind is calculated by WAsP. Furthermore, an estimate of the actual, annual mean energy production of a wind turbine can be obtained by providing WAsP with the power curve of the wind turbine in question.

**Calculation of wind farm production**. Given the thrust coefficient curve of the wind turbine and the wind farm layout, WAsP can finally estimate the wake losses for each turbine in the farm and thereby the net annual energy production of each wind turbine and of the entire farm, i.e. the gross production minus the wake losses.

The program thus contains analysis and application parts, which may be summarised as follows:

**Analysis**

time-series of wind speed and direction —> wind statistics

wind statistics + site description —> wind atlas data sets

**Application**

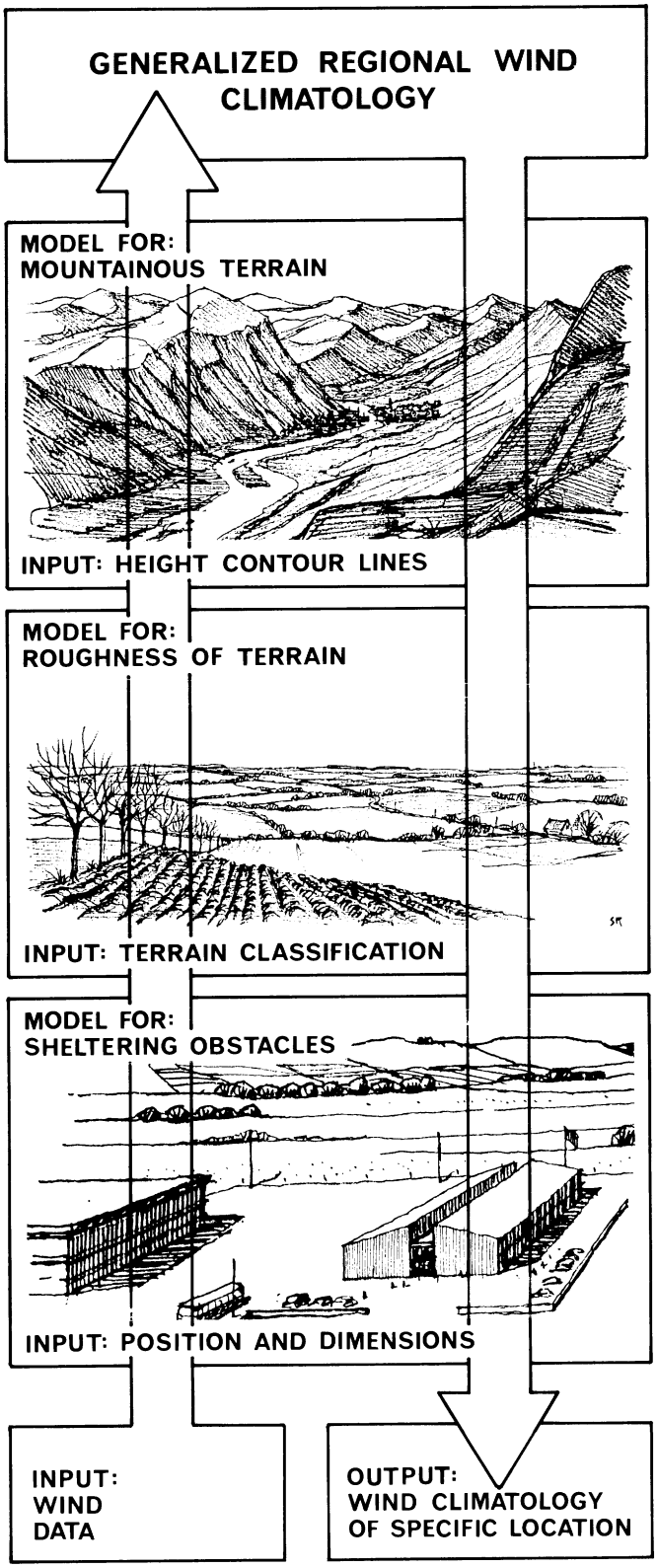
wind atlas data sets + site description —> estimated wind climate

estimated wind climate + power curve —> estimated power production

**Wind farm production**

estimated power productions + wind turbine & farm characteristics —> gross and net annual energy production of each turbine and of entire wind farm

The WAsP models and the wind atlas methodology are described in more detail in the European Wind Atlas.




*The wind atlas methodology of WAsP. Meteorological models are used to calculate the regional wind climatologies from the raw data. In the reverse process — the application of wind atlas data — the wind climate at any specific site may be calculated from the regional climatology (Troen and Petersen, 1989).*

## 1.3 WAsP 8 installation

This brief guide describes the first general release of the installation program for WAsP 8. Great care has been taken to ensure that this installation will run successfully, but as with all Windows software installations, there is a risk that running it could upset the normal functioning of your system. It is recommended that you exercise some caution in choosing when to run this installation program. Please contact the Risø WAsP team before installing if you need any specific advice. To use the full range of features in a software product from Risø, you must have a valid product licence. The installation is therefore divided into two separate steps:

- Installing the WAsP software (this topic)
- Installing the WAsP licence (read here)

### 1.3.1 The installation disk

The WAsP 8 installation files are shipped on a CD-ROM, which contains the following software packages:

- WAsP 8.0 for Windows 98/Me/NT4/2k/XP
- WAsP help file and on-line documentation
- The WAsP Map Editor
- The WAsP Turbine Editor
- The Risø Licence Manager
- Internet Explorer 6.0 (SP 1)
- www.WINDPOWER.org (3.0)
- Golden Software demos and brochures: Didger, Surfer, Grapher and MapViewer.

### 1.3.2 What's been taken out?

The following software packages are not shipped on the WAsP 8.0 CD:

- WAsP 4.2 (16-bit, DOS)
- WAsP 5.2 (32-bit, DOS)
- The DXF-file Translator (DOS)
- The RIX Calculator (DOS)

The WAsP Map Editor can now import DXF-files and the RIX calculator is now fully integrated into WAsP. The DOS versions of WAsP will not be developed and supported anymore.

### 1.3.3 System requirements

WAsP 8.0 will work with Windows 98 (second edition), ME, NT 4.0 (service pack 6a), 2000 and XP (home and professional). Windows 95 is no longer supported. If you are running Windows 98 or Windows NT, then you must have Internet Explorer 5.01 or later installed.

### 1.3.4 Before you install WAsP 8

If running Windows 98 or NT4, make sure that you have Internet Explorer 5.01 or newer installed. If not, you may install the English version of Internet Explorer 6 from the WAsP CD: run the program Ie6setup.exe in the folder \IE6\FLAT\WIN32\EN and follow the instructions. If you have an International Language version of Windows 98/NT4 and Internet Explorer, you should get the corresponding update files from the Microsoft Download Center and not install it from the WAsP 8 CD.

### 1.3.5 Installing WAsP 8

First, close all active programs running on the PC. If the installation files which you are using are located on a network drive, we recommend that you make a copy on your local hard drive and then install using the local copies.

We are distributing the release as a Windows Installer package called Wasp8Setup.msi. If your computer recognises this type of file, then just double-click on it to begin installing the software. If your computer doesn't recognise the MSI-file (it's just about possible if you are running Win98 or WinNT without MS Office), then you can run the alternative installation Wasp8Setup.exe file instead. This will first set up the Windows Installer and then launch the actual installation. You may need to reboot before the installation can continue. Running this file instead of the MSI file will not cause any problems, even if you already have the Windows Installer on your computer

As with any other power tool you should 'read, understand and follow the instructions'; in this case those given by the installation wizard. Agree to the default values and folders suggested by the installation program unless you are absolutely sure of what you are doing. WAsP 8, some utility programs and sample data files will then be installed in the folder C:\Program Files\Wasp and several sub-folders. It will also appear in the Start menu, as a 'WAsP' folder under the Programs menu item. Finally, install the WAsP Map Editor by invoking the file MapEditorInstall.msi and the WAsP Turbine Editor by invoking TurbineEditorInstall.exe.

WAsP, some utility programs and sample data files will be installed in the folder \Program Files\Wasp and several sub-folders. They will also appear in the Start menu, in a 'WAsP' folder under the Programs menu item.

### 1.3.6 Upgrading from WAsP version 7

If you are already running WAsP 7.3, then it is perfectly safe to install WAsP 8.0 as well. Both programs will work without problems, and you can even run them simultaneously. It might be helpful to have an overlap period when both programs are installed, so that you can compare their behaviour.

If you decide to install WAsP 8.0 alongside WAsP 7, then please install them to the same folder. This will ensure that if and when you subsequently remove WAsP 7, WAsP 8.0 will still work correctly. When you want to remove WAsP 7, use the Control Panel Add/Remove Programs applet. When WAsP 7 is removed, and you next try to start WAsP 8.0, Windows will do a quick re-configuration job to make sure that version 8.0 will run again. At this point, you may need to have access to the original WAsP 8.0 installation file.

Like version 7, WAsP 8.0 will not perform calculations unless a valid licence is installed. Version 7 licences and version 8 licences are different, so you need a new licence for this version. You can install the different licences on the same computer and both version 7 and version 8 will work.

### 1.3.7 Installation as an administrator

On Windows 2000 and XP, if you are logged in as an administrator, you can opt to install the software for all users of the computer, not just yourself. If you choose to do that, then the software will be configured separately for other users of the software when they first

run it. On Win2k this is usually the next time that they log in, and on WinXP it's when they first try to launch the software from the Start menu. The per-user configuration will usually require access to the original installation files, so this will not work if you performed the administrator install from a CD which was subsequently removed, or from a network share to which the user does not have access. It's best to make a local copy of the installation file and use that for the original installation.

### 1.3.8 A note for WAsP Engineering users

If you have WAsP Engineering installed, please check that you have upgraded to version 1.2 before installing WAsP 8.0, because there is a risk of some incompatibility between WAsP Engineering 1.0 and WAsP 8.0. If you have not yet received your WAsP Engineering upgrade, then please contact the support staff at wengsupport@risoe.dk.

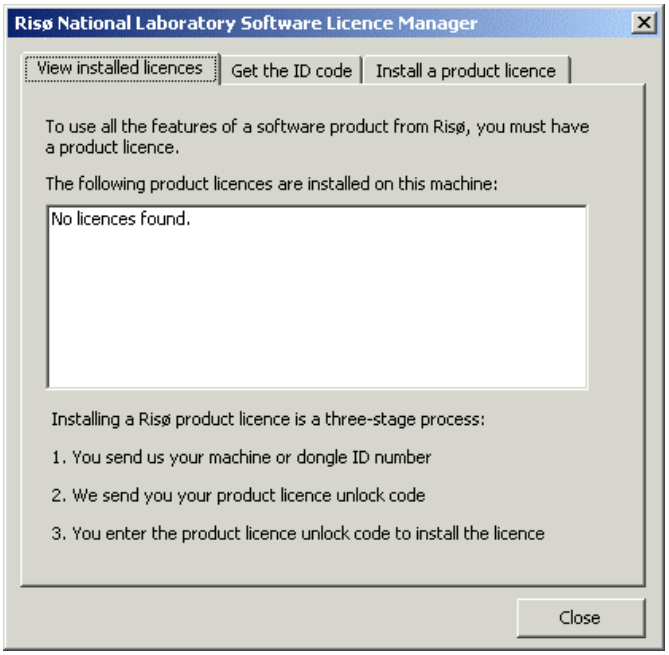
## 1.4 WAsP 8 licencing

WAsP 8.0 will not perform calculations unless a valid licence is installed. Because of the problems experienced by some users with the version 7 licencing system (the machine code ID changed rather more often than we expected), we have introduced an alternative mechanism which we hope will simplify matters greatly.

Together with the WAsP 8 package, you will receive a hardware 'dongle' for your parallel port, and a licence code which matches the dongle. You no longer need to email to us to receive a licence code, and you can swap the dongle around among different machines.

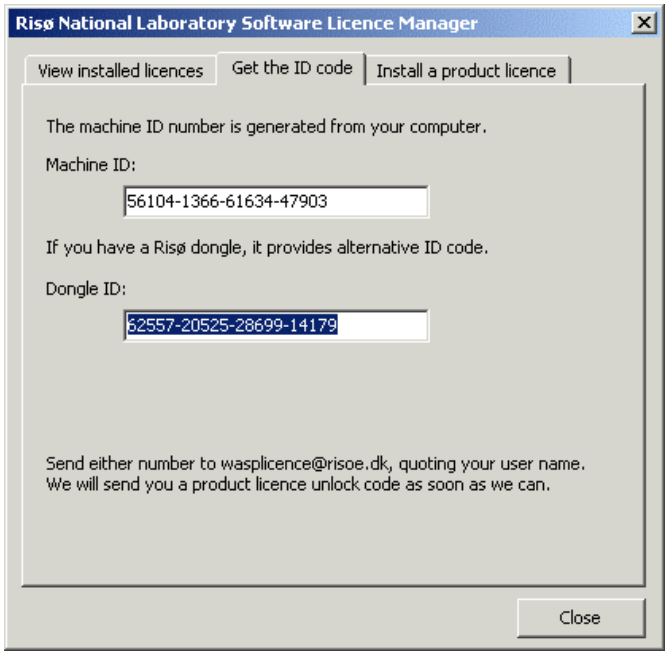
### 1.4.1 Installing the WAsP licence

First, install the WAsP 8 software as described in the WAsP 8 Installation topic. Next, insert the hardware dongle in the PC's printer port. Go to Programs in the Start menu, and launch the program called 'Risoe Licence Manager' from the folder WAsP\Licencing.

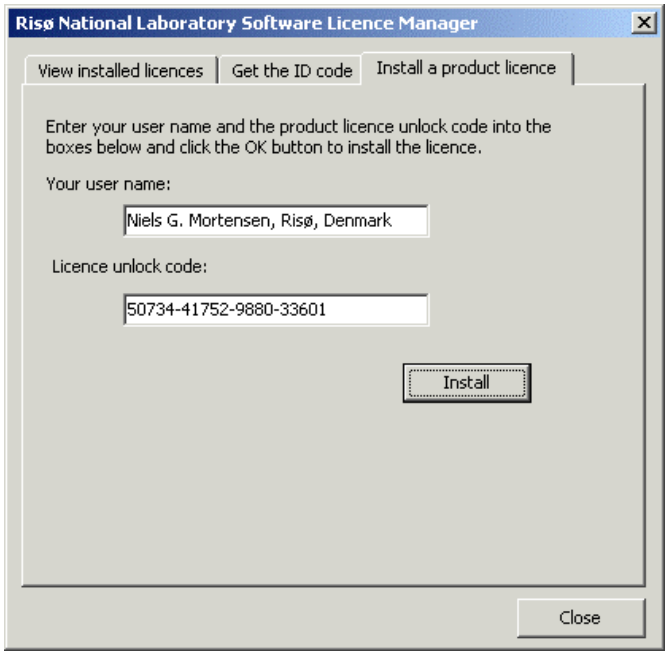



The Licence Manager will show a list of currently installed licences. If you have previously installed a WAsP 7.0 licence, then it will appear here. You can safely proceed: the existing licence information will not be overwritten.

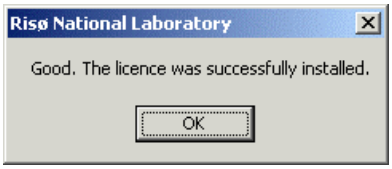
Click the middle tab on the window to show the page called 'Get the ID code':



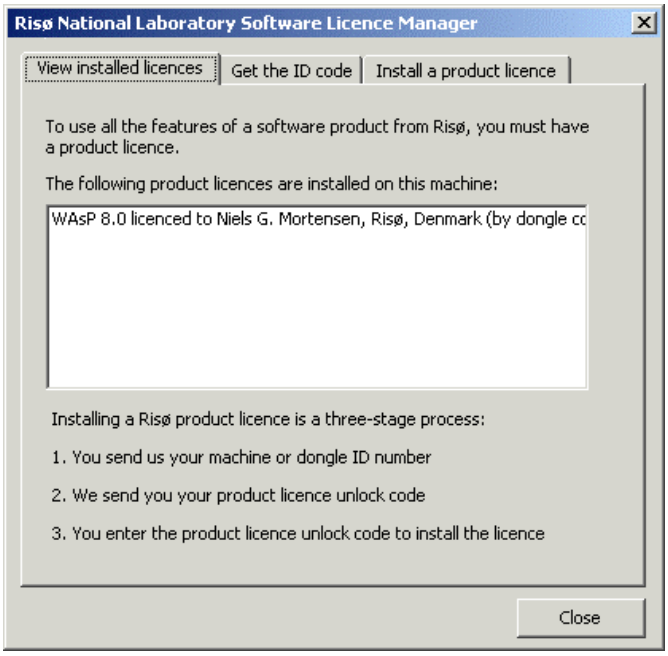

If the dongle has been successfully recognised, then a code should appear in the Dongle ID box. If not, then the words 'No dongle is attached' will appear. Click the right-hand tab on the window to show the page called 'Install a product licence'. Type in the user name and licence unlock code which was supplied with the dongle:




Type in the user name and licence unlock code which was supplied with the dongle exactly as it is written by Risø; including spaces, special characters and punctuation marks. Press Install. A message box should appear saying: 'Good. The licence was successfully installed':

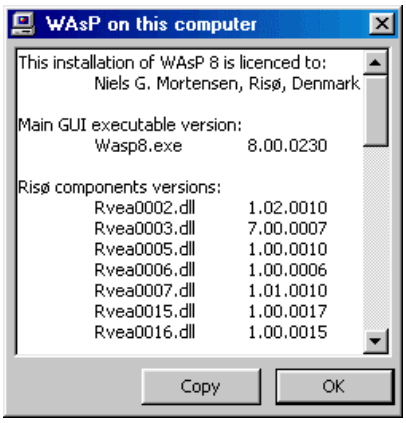


Click on the left-hand tab on the window to show the page called 'View installed licences':




One item in the list should say 'WAsP 8.0 licenced to [your user name] (by dongle)'. If you have already installed a machine-ID WAsP 7 licence, then there will be two entries for WAsP on the list.

When the user name and license unlock code have been entered correctly, the full functionality of WAsP 8 can be utilised. The User Name can be displayed any time in the WAsP Help menu under the menu point WAsP on this computer...




### 1.4.2 Setting up dongle licencing on multiple computers

Using a dongle, it's possible to install the software for use on more than one computer. You need to go through the licencing procedure described above on each computer, but after that chore has been performed, you can switch between using the software on different computers.

### 1.4.3 Problems which you might encounter

**My computer doesn't see the dongle**

If the Dongle ID box in the licence manger program shows the words 'No dongle is attached', then something is amiss. Check that the dongle is correctly inserted in the parallel port. If that is not the problem then try re-running the installation program. Make

sure that all Risø software is closed before running the installation. If the computer still doesn't see the dongle, then please contact WAsP technical at waspsupport@risoe.dk. We will need to do some further investigations.

**I attached the dongle after starting WAsP, but I can't do calculations**

WAsP checks the licence status when it starts, and remembers it thereafter: the startup licence status is actually displayed in the main window title bar. If you add the dongle while WAsP is already running, the licence status is not updated, even though if you check in the 'WAsP on this computer' dialog box, the dongle licence will have been recognised immediately. You need to restart WAsP after inserting the dongle in order to refresh the licence status.

**Dongle-related problems**

We're using a dongle called HASP from a company called Aladdin. According to their technical support web pages, there is a chance that on some systems, using the dongle with a printer may cause problems. You can find more information on their support pages at http://www.ealaddin.com/.

**Installation fails with Error 2744 or Error 1722**

If the installation fails, and shows you a message box with error number 2744 or 1722, then it's probably because your machine al-ready has the device drivers for HASP dongles installed, and the installation cannot replace them.

Please try the following - or contact your system administrator and ask him/her to try it for you. Don't proceed unless you're confident that you can perform all these steps. If in doubt, then please contact waspsupport@risoe.dk for more help.

1. Open the "Add or Remove Programs" window in the Control Panel (under Settings on the main menu)

2. Look for an entry called HASP Device Driver.

3. Remove the HASP device driver

4. Run the WAsP installation again

When the WAsP installation has finished, you may want to re-install your HAsP drivers again, to ensure that you have the latest version. If you don't have the originally downloaded file, you can get it again from the Aladdin web-pages at http://www.ealaddin.com/support/hasp/enduser.asp#latestdd

**Other problems**

Please report any difficulties to waspsupport@risoe.dk, even if you manage to work around them yourself. Then we will be able to try to fix them before the next release.

## 1.5 Getting started...

We suggest you start by reading through the 'Introduction' section of the WAsP help facility. If you are already using the existing versions of WAsP, you might read on in the 'Notes for users of previous versions' section. Next, we recommend that you work through the Quick Start Tutorial - to see for yourself what WAsP 8 is all about.

The documentation and User's Guide to the WAsP 8 program are contained in the WAsP help facility. Here you should be able to find most of the information required to run WAsP. The European Wind Atlas (Troen and Petersen, 1989) contains background information that may not be included in the help file with this release.

If you have problems using the WAsP software please send e-mail to

waspsupport@risoe.dk. If you do not have e-mail, you may send a fax to the number given on the reverse side. You should also check the list of known issues at www.wasp.dk or the list of Frequently Asked Questions (FAQ).

### 1.5.1 Keeping your installation up to date

The latest version of the WAsP 8 program can be downloaded from www.wasp.dk in the form of an update file to the main installation on the CD-ROM. Note, that it will only run on the PC computer where the original WAsP installation was made. Updates of other WAsP 8 files and programs may be available as well (WAsP help facility, Turbine Editor etc.)

### 1.5.2 www.WINDPOWER.org

For general information about wind power, as well as links to other web sites related to wind power, a good place to start is the award-winning home page of the Danish Wind Turbine Manufacturers Association. A recent download of the entire home page is provided for your perusal on the WAsP 8 distribution CD in the folder 'Windpower'. The pages exist in English, German, French, Spanish and Danish and may be read with Internet Explorer 4/5 or Netscape 4. To start reading, Open the file index.htm in any of the five folders English, Deutsch, Francais, Espanol or Dansk. The actual home page can of course also be accessed over the Internet. Acrobat Reader is required to read some of the documents; you may download this from www.adobe.com.

This comprehensive source of information is brought to you by courtesy of the Danish Wind Turbine Manufacturers Association. Please observe the copyright statements and other conditions for use given in the pages.

### 1.5.3 Trademarks and copyrights

Company and product names mentioned in this installation guide may be trademarks or registered trademarks of their respective companies. Please observe the copyright statements provided with each software package on the WAsP 8 CD-ROM.

## 1.6 What's new in WAsP 8?

Compared to previous versions, WAsP 8 contains new functionality, an improved user interface, an improved help facility and several new or updated auxiliary software packages. Among some of the major changes and additions compared to previous versions are:

- New power production calculation procedures implemented, see below
- New wake loss model and wind farm efficiency calculations implemented
- New workspace and project members: these now contain data as well
- New wind farm structure and wind farm file support
- New wind turbine generator window and wind turbine file support
- Obstacles can now influence wind farm turbine sites as well
- New reporting and scripting facilities
- New file formats and file format support
- WAsP help facility updated and expanded
- Wind turbine generator library updated

- A new WAsP Turbine Editor is included
- Internet Explorer 6.0 (SP 1) included

### 1.6.1 New power calculation procedures

Prior to WAsP 8, the total power production of wind turbines was calculated from the total *A*- and *k*-parameters of the predicted wind climate. This has now been changed: in WAsP 8, the total power production is now calculated as the sum of the sector-wise power productions, which are in turn calculated from the sector-wise Weibull parameters. For this reason, WAsP 8 may not give exactly the same results as previous versions of WAsP even with exactly the same input data! We believe that the new procedure in most cases will lead to more representative and accurate results.

### 1.6.2 A brief introduction to WAsP 8

The changes introduced by the move from DOS to Windows with WAsP 6.0 were largely limited to the GUI. We introduced a couple of new file types, and changed two file formats, but the arrangement and operation of the underlying models and data formats remained broadly similar. The move to WAsP 8.0 is rather different. Visually, version 8 is pretty similar to versions 6 and 7. The workspace hierarchy concept is virtually identical, and the visual presentation of data has been significantly improved but not radically altered. "Under the hood", however, things have changed dramatically. We've drawn on the experience of developing WAsP Engineering to implement some major architectural changes.

**Changes to the hierarchy**

We've tried to tidy things up, but the changes are rather minor:

User corrections are no longer separate hierarchy members: they are maintained as part of the members to which they apply.

There is no longer a PWC hierarchy member: the turbine site member also represents the results data for a turbine site.

Wind farms are now simply collections of individual turbine sites for which wake interference can be calculated. Turbine sites can be moved in and out of wind farms, and each site in a farm can have its own wind turbine generator and each can have a different height.

Obstacles will be able to be positioned in various places in the hierarchy: for example so as to affect a group of turbines, or all of the members of a project.

Members at the workspace level are no longer 'seen' as calculation associates by calculating members: all of the members used in a calculation must be in the same project.

In future releases, we will introduce some further changes:

Wind farms will be able to have nested sub-groups of turbines.

**New file format for describing wind turbine generators**

We've developed a new XML file format for describing wind turbine generators, which allows multiple power curve & thrust curve sets to be associated with single type of turbine. Each set can be associated with a particular air density. We're not expecting that this file format will be very rapidly adopted, so for now we are continuing to allow simple POW file imports, but with some constraints. We now require that a thrust curve is contained in the file. It's still possible to open TRB files, but these must have power and thrust curves which are identically organised.

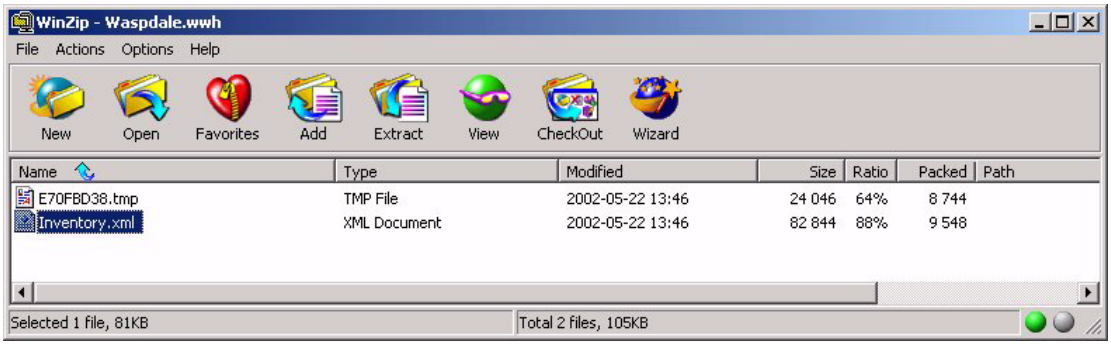
**A workspace file *contains* the workspace data**

A WAsP workspace is no longer stored as an ASCII file containing a list of other files which are stored elsewhere on the machine. Instead, the entire Workspace is stored in a single ZIP archive. The files are smaller, self-contained, and guaranteed to be complete. A copy is a copy, so backing up is easy.

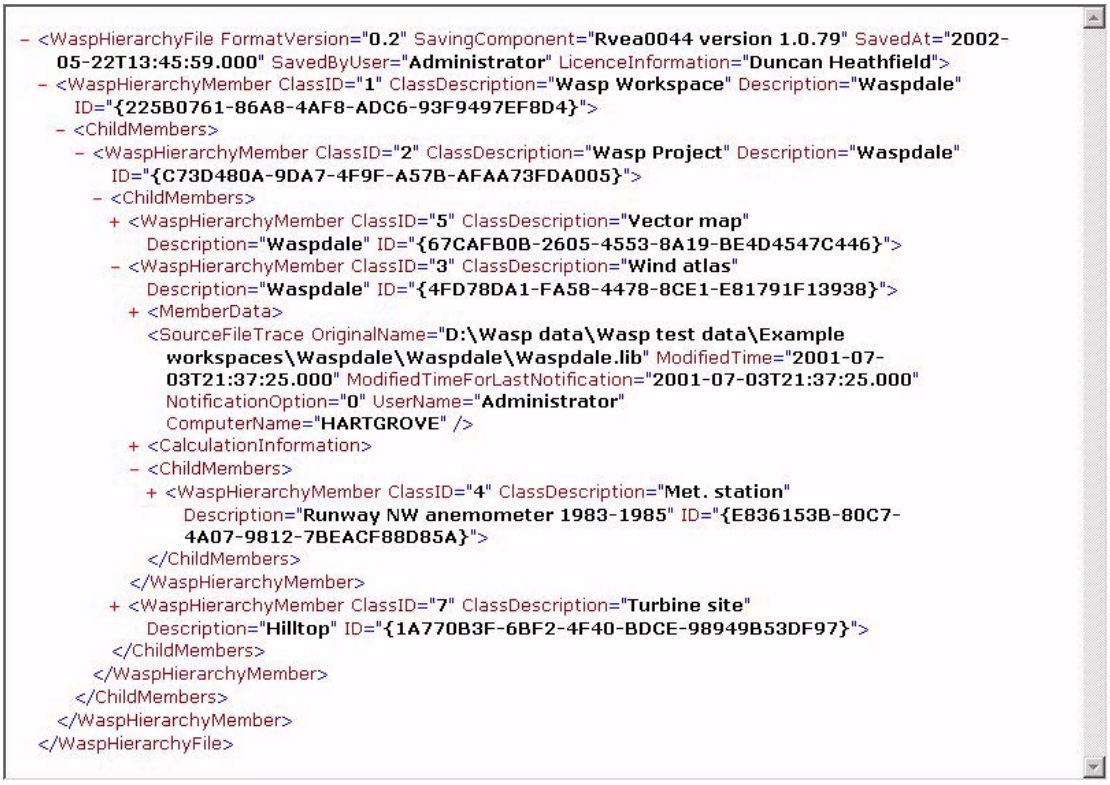
When a file is imported to WAsP to add a member to the hierarchy (for example a map or wind atlas), the data are *copied in* to the workspace, and the original data file is thereafter independent. WAsP remembers where the file came from and every time a workspace is opened, the previously imported files are checked. If they're still where they originally were, and if their data have been updated since they were imported, then you get a warning and an opportunity to re-import them.

The workspace zip file contains simply zipped data files for large discrete lumps or data (map files and resource grid results) as well as an XML file called the inventory. The inventory includes most of the data from the workspace, saved in XML format.

Here's a version 8.0 Wasp hierarchy file (it can be used to save any part of a hierarchy, such as a project). You can just open them in WinZip to see what's inside.




The tmp file there is just the map. You can extract it to disk and it's just the same as a standard WAsP map file. The inventory XML file can also be extracted and viewed in Internet Explorer, for example. Here's a screen capture showing the Waspdale workspace inventory. For readers unfamiliar with reading XML in IE, note that the little plus and minus signs indicate an expandable/collapsable tree. There's a lot of data there buried in the depths of the file.




So, that's how we've done it. It's the same approach as we used in WAsP Engineering, and it's worked well.

**Backward compatibility**

We've implemented an import facility to open projects, workspaces, resource grids and wind farms saved with version 7. Other hierarchy members can be simply opened into the hierarchy from file as before. This is true for obstacles, wind atlases, maps, roughness roses, observed wind climates, wind turbine generators. All the version 7.0 file formats are supported.

We have no plans to support exporting version 8.0 workspace or project files in version 7.0 format.

Although the data are now all stored in the workspace file itself, individual hierarchy members' data can be exported to file, with a choice of new formats or version 7.0 formats. This is true for obstacles, roughness roses, wind atlases, observed wind climates, resource grids and wind farms.

**Resource grid output**

Users can right-click on a resource grid and select 'Export to file', and get a file which is 100% compatible with the previous version's output.

Indeed, the resource grid results are now saved to the workspace file as surfer grid files which are zipped into the workspace archive.

Resource grid output can now be exported map-by-map as Surfer ASCII GRD files. From within the resource grid window, the user can select a result variable (such as omni-directional Weibull-A), and save it out as a Surfer file for external analysis. The GUI in the version 8.0 release will only support omni-directional results, but we plan to provide full sectorwise output access in subsequent versions. When a resource grid is exported as an RSF file, the sectorwise results are all calculated and stored, of course.

**Wind farm output**

Wind farm results can be exported to version 6 (rsf) and version 7 (wwf) formats. An alternative way to view the data (and one which allows access to a lot more useful information), would be to read data about the wind farm as saved to a version 8.0 workspace inventory file.

**Reports**

At last, we have provided proper support for reports. Users can generate reports on various members of the hierarchy such as met. stations and wind farms. These reports contain a mixture of text, tables and graphics, and are written as standard HTML and launched for viewing/manipulation/saving/printing. Other possible output report formats include MS Word or Excel. With the version 8.0 release, we'll provide a standard set of reports, but this standard set will be expanded over time, and perhaps we'll be involved in developing custom reports for clients with particular needs.

**Architectural changes to support reports and scripting**

As with WAsP Engineering, the reports are generated according to scripts, written in VBScript, and saved as ASCII files. These can be developed after compilation of the program and dropped in. This system is open: we're expecting that power users will soon start tweaking the standard reporting scripts, and possibly developing their own. At the time of writing, there are no plans to introduce any restrictions on users who want to do that, but at first we won't provide any support or documentation.

Scripts which run from within WAsP are not restricted to producing report output, and can actually be used to examine and even manipulate the currently opened workspace. We're expecting to discover many uses for this, such as automating tedious work and performing 'expert' analysis of workspaces, but again, we don't plan to provide any support or documentation at first.

To make this all possible, we've split WAsP in two: the GUI is now completely separate from the modelling code. This architectural change also makes it possible to work with WAsP programatically without using the GUI program at all. We have already been using the WAsP 8.0 models from within Excel's VBA environment, for example, allowing us to evaluate the effect of varying a particular parameter value and getting results written out to the spreadsheet ready for analysis. (When WAsP 8.0 is released, it will be locked to make a special licence necessary to work with the models without the GUI running.)

These architectural changes make possible two new ways for other software to interact with WAsP:

A script can run inside WAsP itself, passing information out to some other auxiliary component for further analysis. For example, a script could invoke an external component could calculate the optimal arrangement of a wind farm from resource grid results, and then actually set up the resulting wind farm within WAsP automatically.

An external program could manipulate WAsP invisibly to extract the results it needed for input.

## 1.7 Known issues

With the release of WAsP 7, the Park model was included in the WAsP program through the wind farm member. In some respects, the wind farm model acts as a separate model and it also has its own settings and dump file.

It is important to note the following:

- WAsP uses an air density of 1.225 $kgm^{-3}$ when calculating power density. Similarly, power production is calculated for this standard air density if one of the sample power curves is used.

- Only if the power curve is specified for the actual site air density, or an existing power curve has been scaled to the site air density (this is only recommended for some turbines though), will the wind turbine power production calculated by WAsP correspond to this air density.

- When invoking Edit in map editor from the map's right-click menu, any changes to the map are not automatically used in WAsP; the map must be saved from the map editor and reloaded into WAsP for the changes to take place.

- The present version of the help facility is not entirely up-to-date: the section on file formats reflects the status as of WAsP version 7.3. An updated version of the help file will be made available on www.wasp.dk as soon as possible. If you need information about a specific file format, please do not hesitate to contact WAsP technical support.

You should also check the list of known issues at the WAsP home page.

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## 1.10 Acknowledgements

The WAsP program was originally developed, designed and implemented by Ib Troen, Niels G. Mortensen and Erik L. Petersen from Risø National Laboratory, with financial support from the Commission of the European Communities (DGXII).

The present Windows-version was developed by a team consisting of Lars Landberg, Niels G. Mortensen, Ole Rathmann and Lisbeth Myllerup from the Wind Energy Department at Risø, Sofus S. Mortensen from Lambda Soft (DK) and Duncan N. Heathfield from World in a Box Finland OY.

The ruggedness index concept was developed and tested by Anthony J. Bowen from the University of Canterbury, New Zealand.

Artistic drawings by Søren Rasmussen.

# 2 WAsP Help Facility

## 2.1 The WAsP help facility

This help facility should eventually become the complete, on-line User's Guide and Technical Reference for the WAsP program. The main characteristics of the WAsP Help Facility are:

- Based on Microsoft HTML help
    - Requires Internet Explorer 4.0 or later for full functionality
- Complete on-line documentation
    - Text, tables and images
    - Table of contents, index and keywords
    - Books and topics can be printed
- Fast and easy to use
    - Context-sensitive help (F1-help)
    - Full-text search facility
- Hyperlinks to topics, URL's and e-mail addresses
- Easy to update and distribute

The help facility can be invoked and used in two different ways: as context-sensitive help or as a stand-alone application/document.

The present version of the help facility is not entirely up-to-date: the section on file formats reflects the status as of WAsP version 7.3. However, the help facility is far from static, but is being developed continuously. New versions will be made available at the WAsP home page and you'll receive a notification when this happens – if you have informed us about your e-mail address.

## 2.2 Context-sensitive help

Pressing the F1-key on your keyboard invokes context-sensitive help for the active window or dialog. This works in the WAsP program as well as for the Observed Wind Climate Wizard. The WAsP map editor has its own help facility.

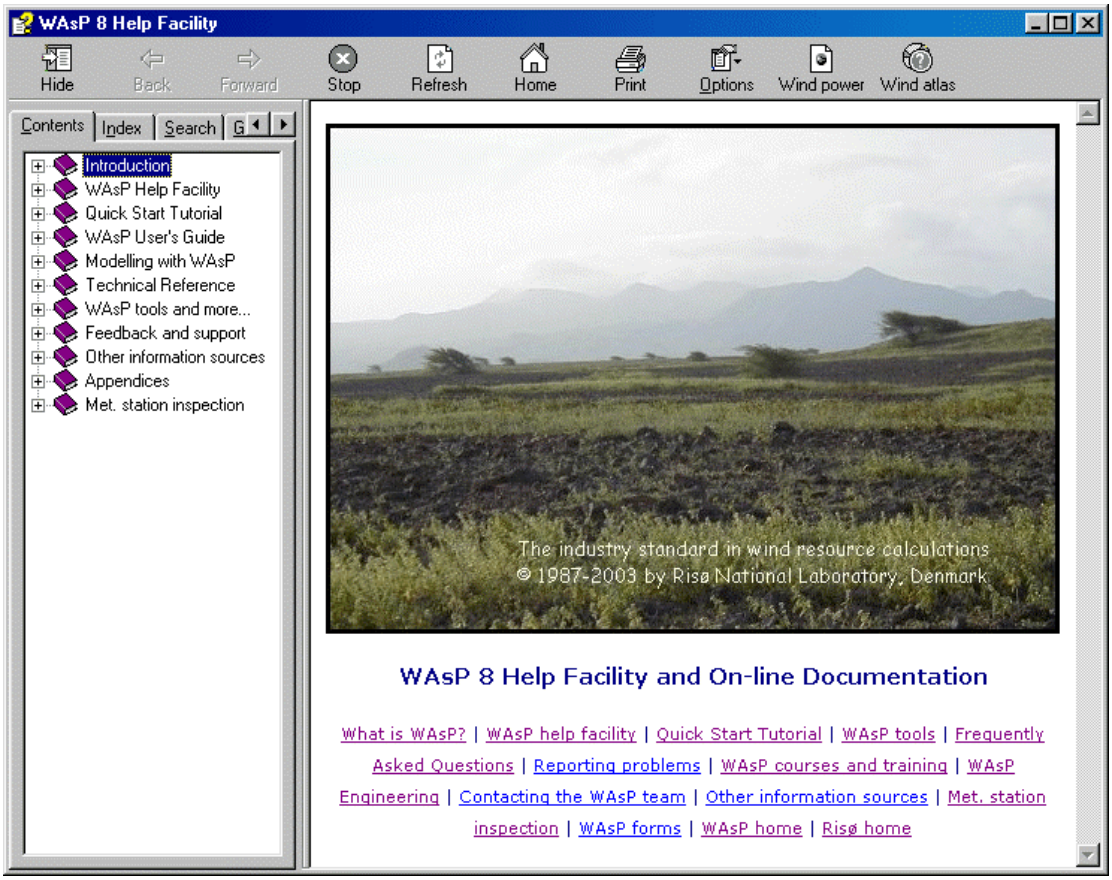
From the WAsP program you are guided directly to the User's Guide of the help facility; to a point from which you should be able to find the answer you're looking for. Use the Contents tab to navigate the help facility via the table of contents, or use the related topics controls present on most F1-help entry pages.

As an example, the obstacle window entry page has the following two controls:


You can also use the Index tab to navigate via the keywords of the index or you can use the full-text search facility by choosing Search.

## 2.3 Complete on-line documentation

The help facility is the complete on-line User's Guide and Technical Reference for the WAsP program package. It can be invoked from the main menu of WAsP by choosing the Contents and Index menu item from the Help menu. Or, it can be invoked from the Start / Programs / WAsP menu in Windows. The opening screen looks like this:




The help facility can be browsed in several ways: you may use the Contents tab to navigate the help facility via the table of contents, or you may use the Index tab to navigate via the keywords of the index. Finally, you may use the full-text search facility by choosing Search.

In the different topics of the help facility you may find links to other topics and to Web pages; these can be invoked directly with the left-hand button of the mouse. Links to e-mail addresses will start your e-mail application when invoked. Topics and entire books can be printed when choosing the Print menu point.

## 2.4 Plan for future editions

The contents of future editions will to some extent depend on the user response to the present version. However, we do plan to add more information on the following subjects:

- Wind power meteorology in general
- Site calibration and customisation
- Limitations of the wind atlas methodology
- Wind resource assessment in specific situations: offshore, near-shore, complex terrain and wind resource mapping.

We also aim at providing more sample data and example projects with the WAsP package.

## 2.5 Bibliographical reference

**Title**: Wind Atlas Analysis and Application Program: WAsP 8 Help Facility

**Authors**: Niels G. Mortensen†, Duncan N. Heathfield*, Lisbeth Myllerup†, Ole Rathmann†, Lars Landberg†, Ib Troen† and Erik L. Petersen†

†Risø National Laboratory and *World in a Box Finland OY

**ISBN**: 87-550-3171-4

**Department**: Wind Energy Department, Risø National Laboratory

**Date**: January 2003

**Topics**: 309

**Tables**: 11

**Illustrations**: 236

**References**: 26

**Abstract**: The Wind Atlas Analysis and Application Program (WAsP) is a PC-program for horizontal and vertical extrapolation of wind data. The program contains a complete set of models to calculate the effects on the wind of sheltering obstacles, surface roughness changes and terrain height variations. The analysis part consists of a transformation of an observed wind climate (speed and direction distributions) to a wind atlas data set. The wind atlas data set can subsequently be applied for estimation of the wind climate and wind power potential, as well as for siting of specific wind turbines. The WAsP 8 Help Facility includes a Quick Start Tutorial, a User's Guide and a Technical Reference. It further includes descriptions of the Observed Wind Climate Wizard, the WAsP Map Editor tool, the WAsP Turbine Editor tool and the Air Density Calculator.

**Descriptors (INIS/EDB)**: COMPUTER PROGRAM DOCUMENTATION; DATA ANALYSIS; MAPS; RESOURCE ASSESSMENT; SITE CHARACTERIZATION; W CODES; WIND; WIND POWER.

**Please refer to**: Mortensen, N.G., D.N. Heathfield, L. Myllerup, L. Landberg, O. Rathmann, I. Troen and E.L. Petersen (2003). *Wind Atlas Analysis and Application Program: WAsP 8 Help Facility*. Risø National Laboratory, Roskilde, Denmark. 309 topics. ISBN 87-550-3171-4.

# 3 Quick Start Tutorial

## 3.1 Introduction

This section of the WAsP help facility is intended to provide a very brief introduction to the essential features and uses of WAsP, in particular how to use the Graphical User Interface (GUI).

A concise explanation of the most basic techniques is followed by a simple step-by-step example.

New users will get an idea of what WAsP is for and how to use it. Existing users of older versions of WAsP will be introduced to the new ways of working.

## 3.2 The GUI essentials

### 3.2.1 Just the basics...

This section is not intended to be a complete guide to using WAsP. Instead, you are introduced to just enough of the basics to let you work through the simple step-by-step example.

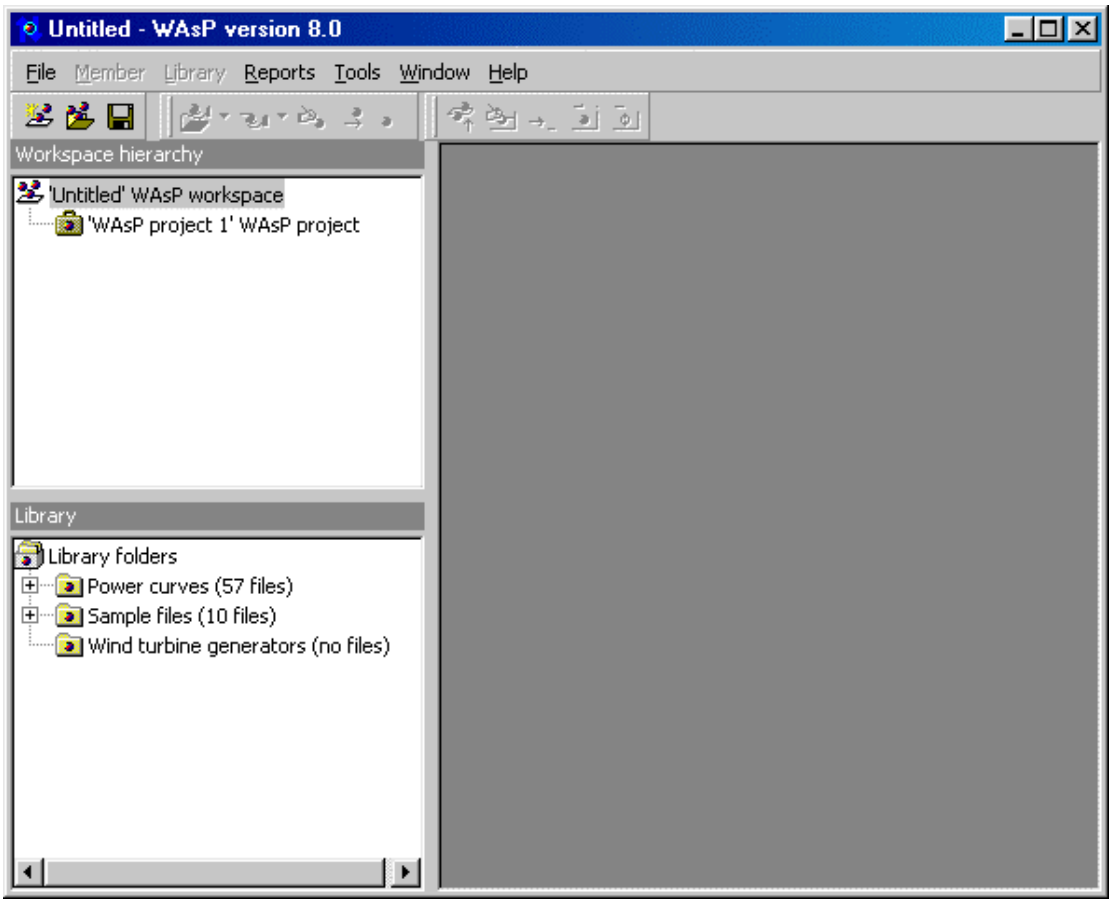
Read through the following sections in order

1. WAsP workspaces
2. Working with the workspace hierarchy
3. Saving the workspace members

This brief introduction is followed by the step-by-step example.

### 3.2.2 Opening a new WAsP workspace

When you first open WAsP, you are presented with an empty window. To start work, you need to open a workspace. In WAsP, all work is performed within the context of a workspace. Workspaces can be created, saved and re-opened. To open a new workspace, select New workspace from the File menu.



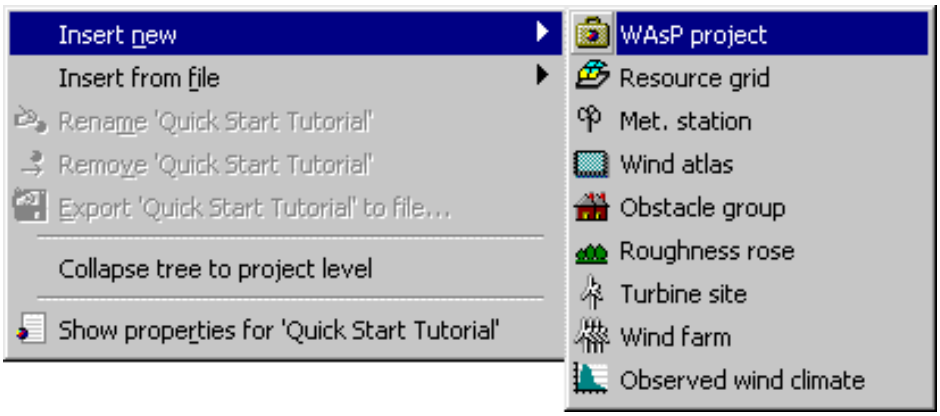

Two white window 'panes' have appeared on the left-hand side of the main window: the Workspace hierarchy and the Library. The library pane simply makes it faster to find files. It is explained elsewhere in the documentation. For now, ignore the library pane and concentrate on the workspace hierarchy, which is the most important area of the program.

### 3.2.3 Working with the workspace hierarchy

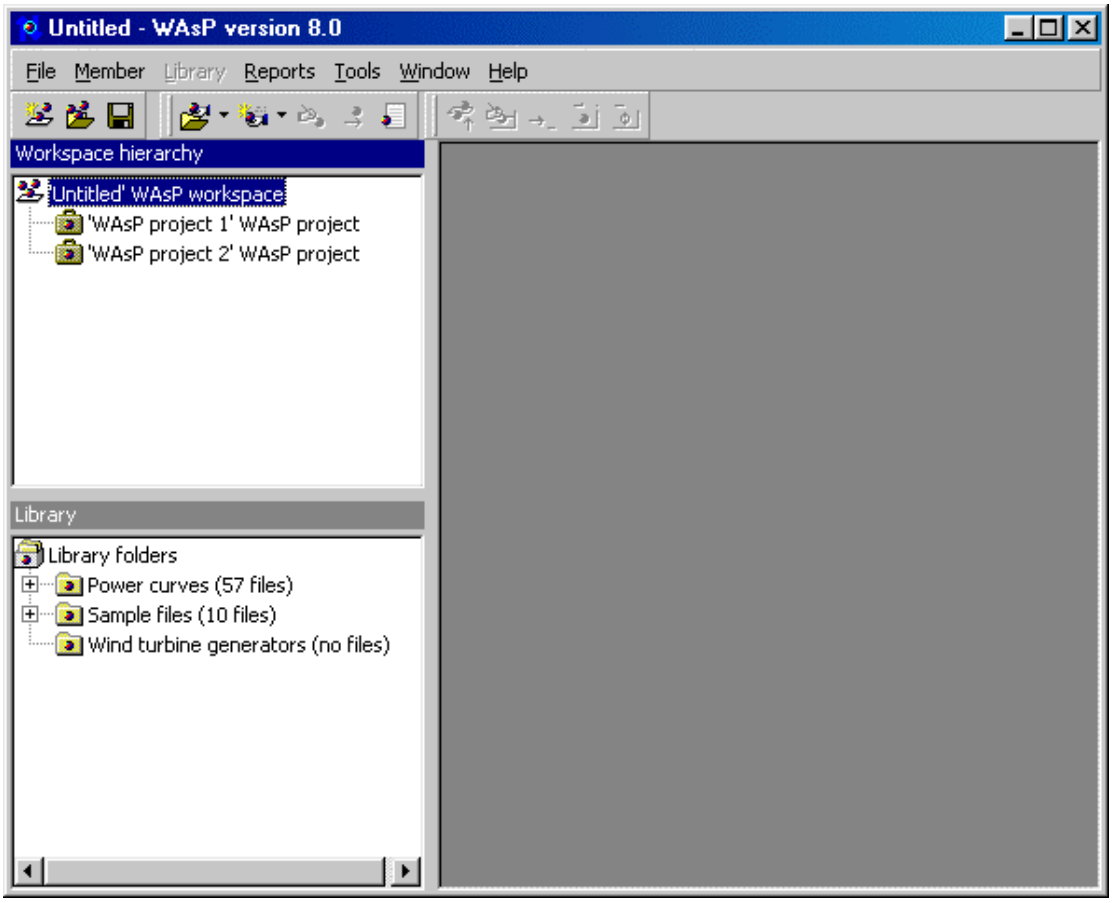
The workspace hierarchy contains one single icon, representing the 'root' of the workspace. This workspace further contains one project: 'WAsP project 1'. To work with WAsP, you need to add new items to the workspace. These items are arranged in a hierarchy and are called hierarchy members or just 'members', for short. The workspace root is always at the very top of the hierarchy. All of the members of the workspace are children of the workspace root.

To insert a new member to the hierarchy, do the following:

- Click with the right-hand mouse button on the workspace icon.
- A small 'pop-up' menu appears. Select Insert new.
- Another menu appears. Select WAsP Project.




A project hierarchy member is inserted as a child of the workspace root.




Every member of the hierarchy has a right-click menu. Most members' right-click menus include insertion sub-menus.

To insert another member to the hierarchy:

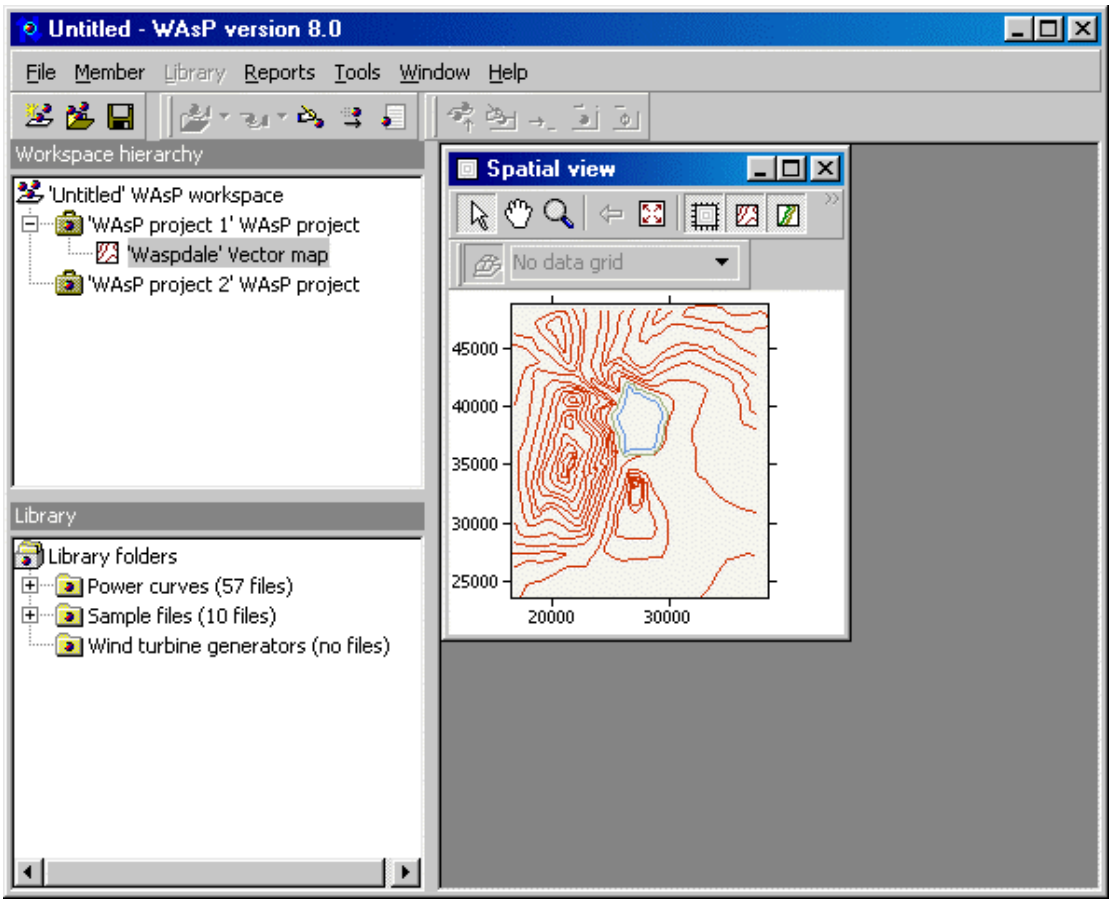
- Select Insert from file from the first projects pop-up menu.
- Select Vector map from the insertion sub-menu.
- A file-choice dialog box appears. Select the file called 'Waspdale.map'.

You may have to navigate to the folder containing the sample data, which was created when you installed WAsP, e.g. 'C:\Program Files\Wasp\Sample data\Wasp misc files'. The map is now a member of the hierarchy, as a child of the first project.

To view the map:

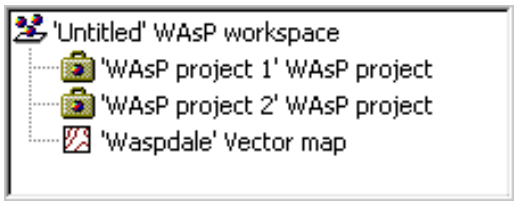
- Select Show in new spatial view from the map icon's right-click menu

The map window appears in the right-hand side of the main window:




Most members in the hierarchy have an associated window in addition to the simple icon, which is displayed in the hierarchy itself.

All members of the hierarchy (except the hierarchy root) can be inserted, moved around or deleted. You can re-organise the existing hierarchy members by dragging them around with the mouse. To move the map so that it is a child of the workspace root, simply drag the map icon onto the workspace icon:




The map and the project are now both children of the workspace root. There are constraints on where different types of hierarchy member can be placed in the hierarchy, but most types of member (including maps) are allowed to be children of the workspace root. Members in the workspace root (except for projects) are passive data files, i.e. they do not have any influence on the calculations in the projects.

You have already learned the most important techniques for working with WAsP!

It is largely a matter of manipulating the members of the workspace hierarchy using the

mouse. Learning to use WAsP is now simply a question of getting to know the various members of the workspace hierarchy and understanding how to use them.

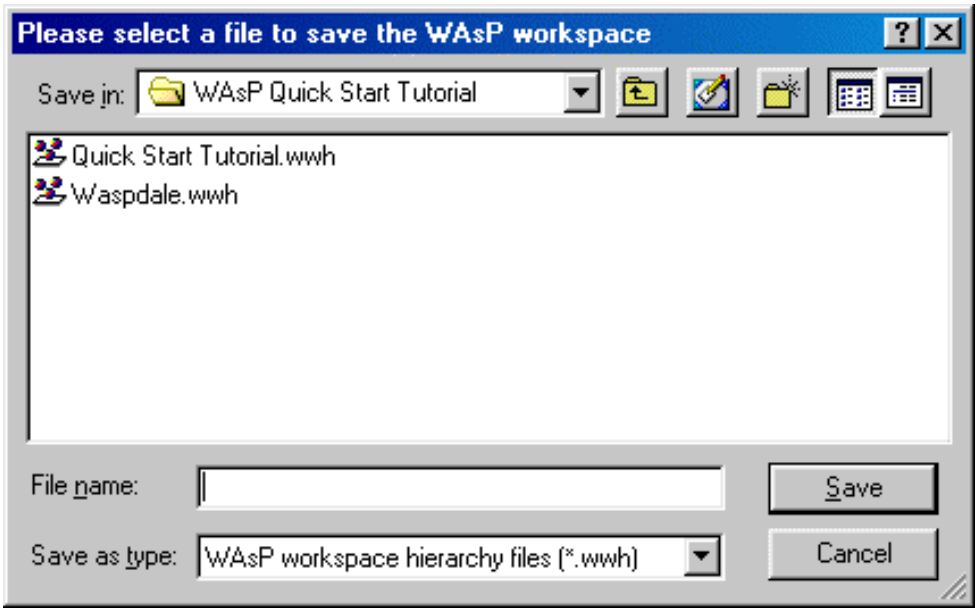
### 3.2.4 Saving the workspace and members

Several members of the workspace may be inserted from associated data files. However, when you work with a hierarchy member in WAsP, you are dealing with a copy of the data and you can make changes to anything. The changes to the data are not written to the file unless you save or export them. The workspace hierarchy and the data it contains are saved in a WAsP workspace hierarchy file (*.wwh).

To save the workspace:

- Select Save or Save as from the File menu.

Type a name in the box, which appears.




When you press Save, the entire workspace and the data it contains are saved. You can also save a project; this is done from the project's right-click menu.

To save the project:

- Select Save project to separate file from the project icon's right-click menu.

Type a name in the box, which appears.

At any time, you can save the whole workspace by clicking on the Save workspace icon in the main toolbar.

## 3.3 A step-by-step example

### 3.3.1 Introduction

The example works through a complete wind turbine siting operation, starting with some measured wind data and ending up with a prediction of the power yield from erecting a turbine at a specific site.

You can find the data used for the example in the folder containing the sample data, which

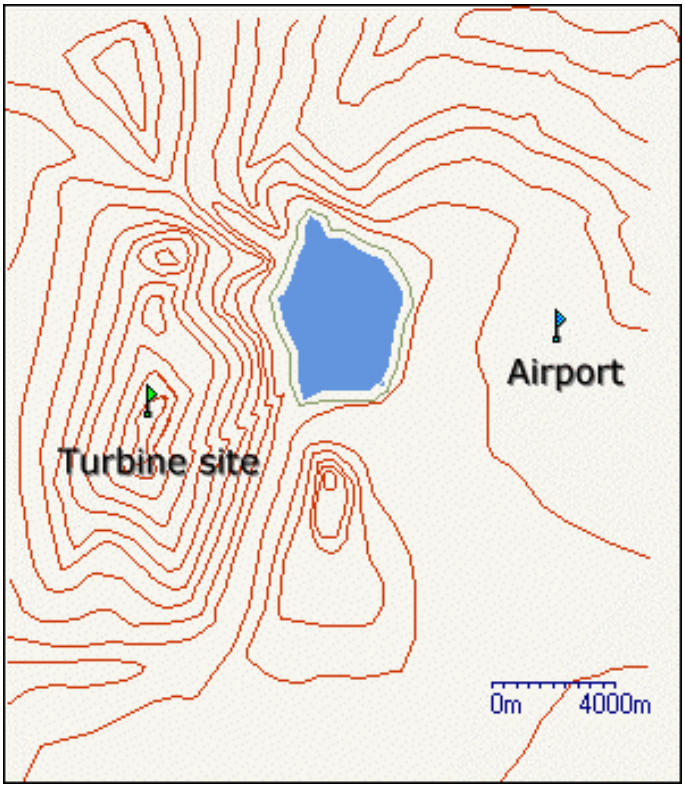
was created when you installed WAsP, e.g. 'C:\Program Files\Wasp\Sample data\Wasp misc files'.

At the bottom of each page is a Proceed... link, which will take you to the next page in the example.

### 3.3.2 The situation

The company *Friends of Wind Energy, Waspdale Ltd.* has asked you to provide a prediction of the power yield from locating a wind turbine in Waspdale. They propose to erect a single 1-MW wind turbine at the summit of Waspdale hill (they have modest energy requirements).

No wind measurements have been taken at the turbine site itself, but data have been collected from a meteorological station at nearby Waspdale airport. A map of Waspdale is shown below.




You are equipped with:

- a contour map of the area
- the wind data from the airport
- a simple description of the land use in the area
- an annotated sketch of the airport buildings near the met. station
- a description of the power-generating characteristics of the turbine

These data have been converted into digital files, as follows:

- a digital map of elevations and roughness
- a data file containing wind data

- a data file describing the buildings at the airport
- a data file containing a power production curve for the turbine

### 3.3.3 Working with WAsP to provide a prediction

From engineering data, you know how much power will be generated by the turbine at a given wind speed. If the plan was to erect the turbine at exactly the same place where the meteorological data had been collected, then it would be a really simple task to work out how much power to expect.

However, just from looking at the map it is obvious that the proposed turbine site is completely different from the meteorological station at the airport: the properties of the meteorological station itself will affect the wind data recorded there. In addition, the properties of the turbine site will have an effect on the way that the wind behaves near the turbine. It is also unlikely that the hub height of the turbine would be the same as the height of the anemometer.

What you need is a way to take the wind climate recorded at the meteorological station, and use it to predict the wind climate at the turbine site. That is what WAsP does.

Using WAsP, you can analyze the recorded wind data, correcting for the recording site effects to produce a site-independent characterisation of the local wind climate. This site-independent characterisation of the local wind climate is called a wind atlas or *regional wind climate*. You can also use WAsP to apply site effects to wind atlas data to produce a site-specific interpretation of the local wind climate.

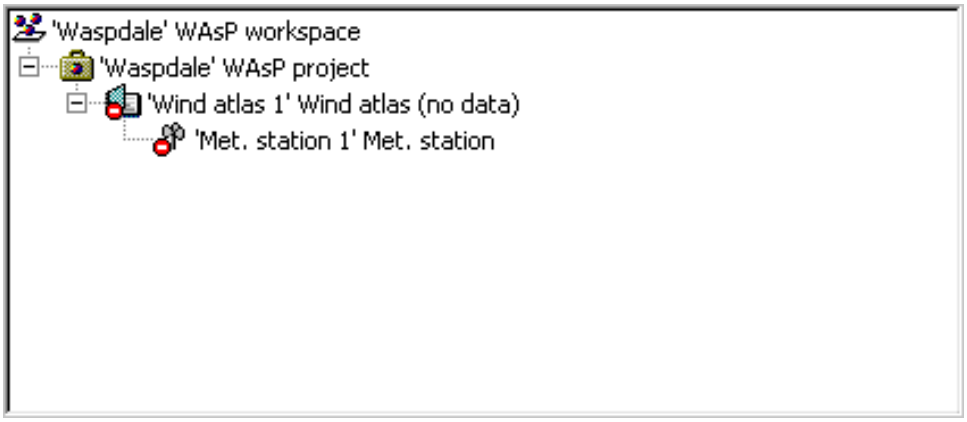
Providing a prediction in the Waspdale case will therefore be a two-stage process. First, the data from the meteorological station need to be analysed to produce a wind atlas, and then the resulting wind atlas needs to be applied to the proposed turbine site to estimate the wind power.

### 3.3.4 Calculating the wind atlas

#### Setting up a met. station

To begin, you need to open a new workspace in WAsP. A new project is automatically inserted in this workspace. Save the workspace and project, calling them both 'Waspdale'. Return to the GUI essentials if you don't know how to do this.

Now insert a new wind atlas as a child of the project (right-click on the project, choose Insert new and then Wind atlas). The wind atlas will be generated from a meteorological station; a new met. station hierarchy member has already been inserted as a child of the wind atlas. The workspace should now look like this:



WAsP now requires:

- a description of the data-recording site
- a summary of the wind data recorded at the site

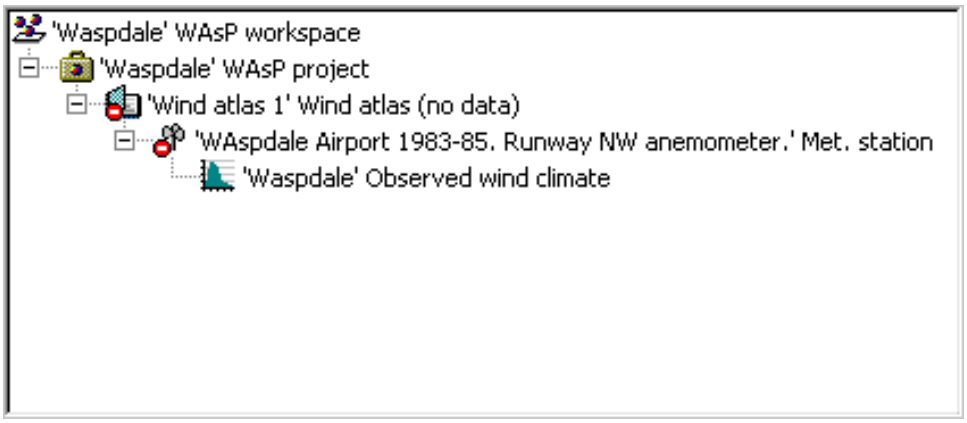
**Adding wind observations**

You now need to insert some wind data to the hierarchy.

Select the met. station and use Insert from file to insert an Observed wind climate member. You will be asked to provide the name of a file to use. Navigate to the folder containing the sample data, which was created when you installed WAsP, and select the file called 'Waspdale.tab'.

You can read more about how to create observed wind climate files from raw data measurements elsewhere in the documentation.

The workspace should now look like this:



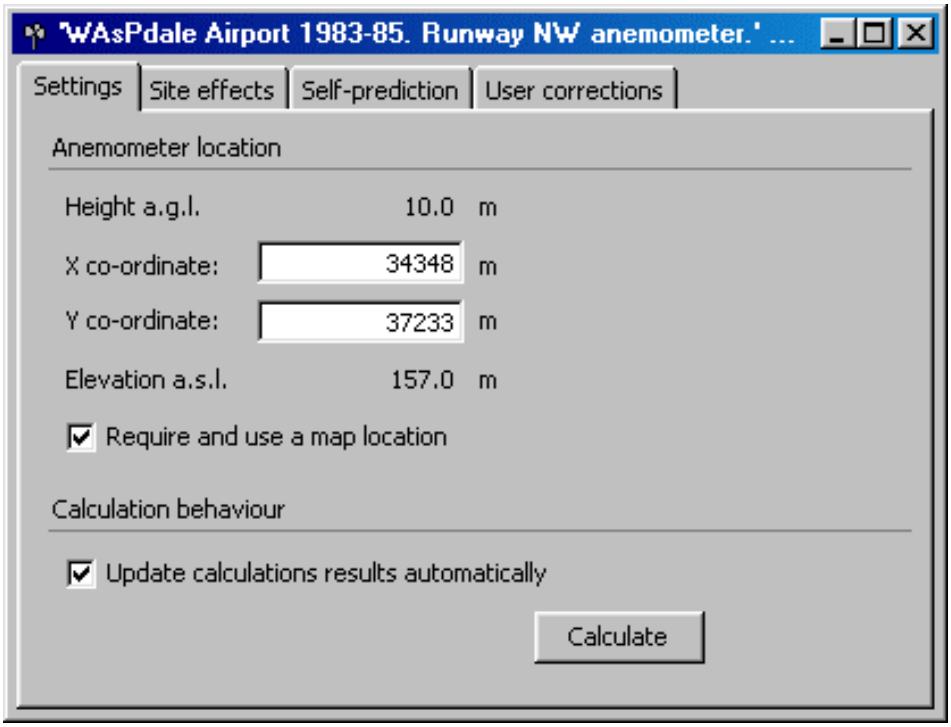

You can provide a new name for the wind atlas and other members of the hierarchy by right-clicking and choosing Rename. Here, call the wind atlas 'Waspdale'.

**Describing the site**

Now WAsP needs to know about the site where the data were collected. First, introduce a map as a child of the project. You should use the project's Insert from file method, then Vector map and then select the file called 'Waspdale.map'. Now you need to locate the met. station in the map.

To locate the met. station:

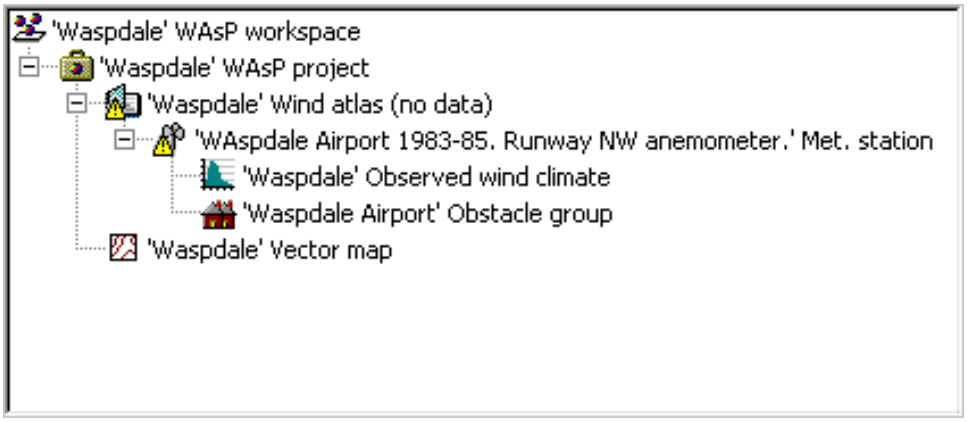
- From the met. station's right-click menu, select Show.
- When a dialog appears, set the location to (34348,37233):




At the met. station site, several buildings and shelterbelts of trees were found in the vicinity of the anemometer mast. WAsP needs to know about these.

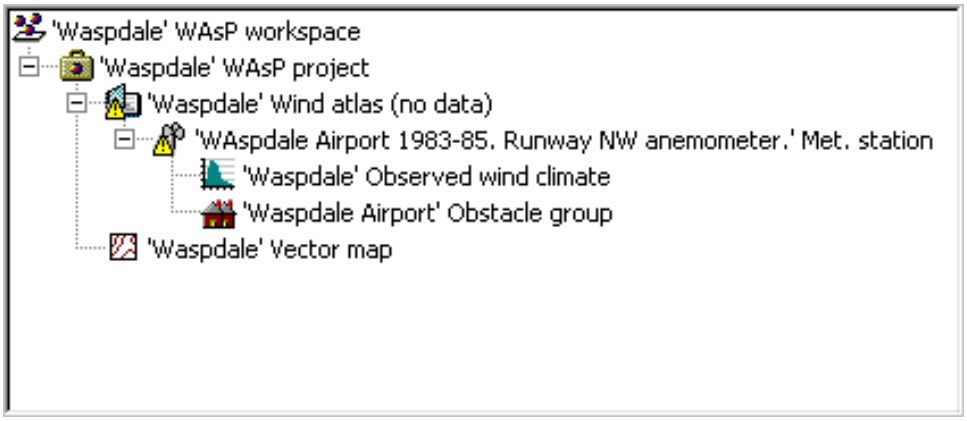
Insert a list describing the obstacles, use the Insert from file method of the met. station to add an Obstacle list. When the choose file dialog box appears, select the file 'Airport.obs'.

The workspace hierarchy should now look something like this:




**The atlas calculation**

WAsP is now ready to calculate the wind atlas for Waspdale, but before proceeding, pause to examine the members of the hierarchy which are contributing to the analysis:




The map, the observed wind climate and the obstacle list all contain data and can be viewed. Each has a command called Show on its right-click menu, which will open the window associated with the member. Open each one and have a look. To see where the met. station is in the map, select the Show in existing spatial view command from the met. station's right-click menu; clicking on the little anemometer icon in the map's toolbar will show or hide the met. station in the map.

Now get WAsP to generate the wind atlas. From the Wind atlas' right-click menu, select the Calculate wind atlas command. When the calculation is finished, the small yellow warning sign shown at the wind atlas icon has gone. This indicates that the calculations for the wind atlas are up to date. You could also have chosen Do any feasible calculations for all project members in the project's right-click menu to update all calculations within the project.

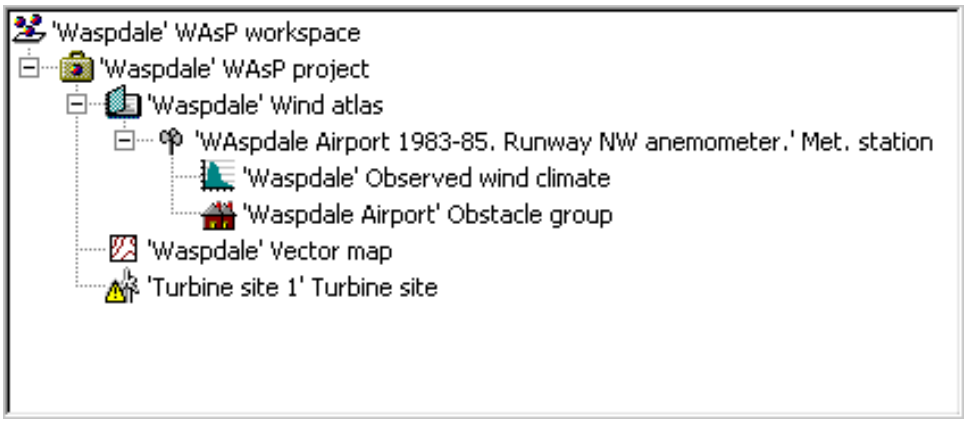
To see the results of the calculation, select the Show command from the Wind atlas' right-click menu. The wind atlas is displayed. This is a site-independent characterization of the wind climate for the entire Waspdale area; you may also think of it as the *regional wind climate* of Waspdale.

### 3.3.5 Estimating wind power

#### Setting up a turbine site

Now that the project contains a wind atlas with site-independent wind climate data, we can apply those data to the proposed turbine site. WAsP will adjust the data for the situation found at the turbine site, and will produce a prediction of the wind climate for the site itself.

You need to add a turbine site hierarchy member to the workspace. Insert a new turbine site as a child of the project. The workspace now looks like this:




Provide a name for the turbine site by right-clicking the turbine site icon and choose

Rename. Call it 'Hilltop', since the plan is to erect the turbine on a hill.

WAsP now requires:

- the location of the site in the map
- a description of the type of wind turbine that you propose to use.

There are no obstacles near the hilltop, so there is no need to add an obstacle list to this site.

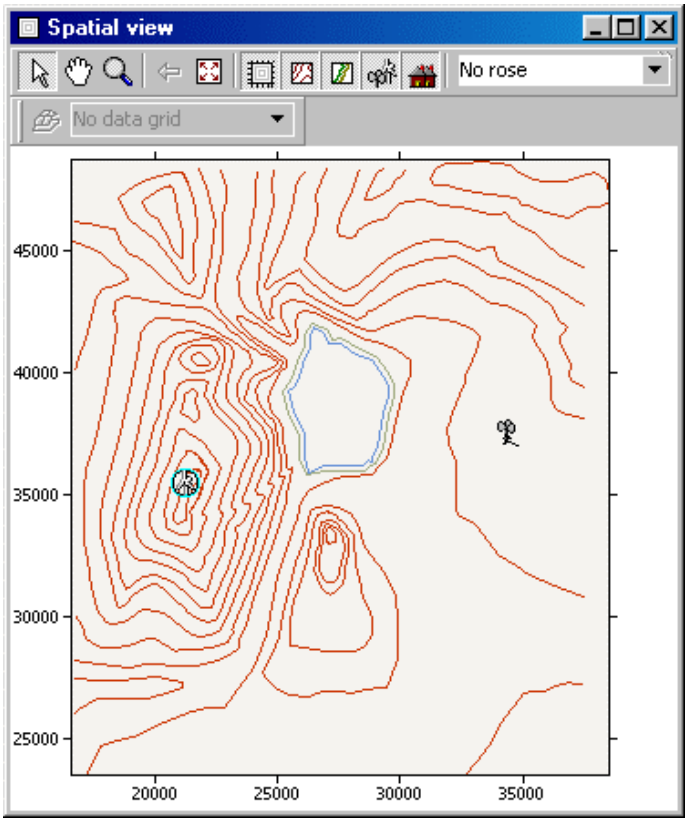
**Locating the turbine site**

First, locate the turbine site in the map. Because the map and the turbine site are in the same project, WAsP automatically knows that the site lies in the area covered by the map. All that you need to do is provide the co-ordinates.

This could be done by following the same procedure as used for siting the met. station (type the co-ordinates into the site dialog box). However, since the location of the turbine site has not been exactly decided, we do not need to be so precise at this stage. We can use a different method.

From the turbine site's right-click menu, select Show in new spatial view. The map window will appear, and the turbine site will be highlighted in the middle of the map area. Click on the toolbar button marked  to shrink the window to see the entire map; you can also maximize the window in the usual way.

It is now possible to drag the turbine site in the map to the location you want. Put it on top of the hill in the west of the area, like this:

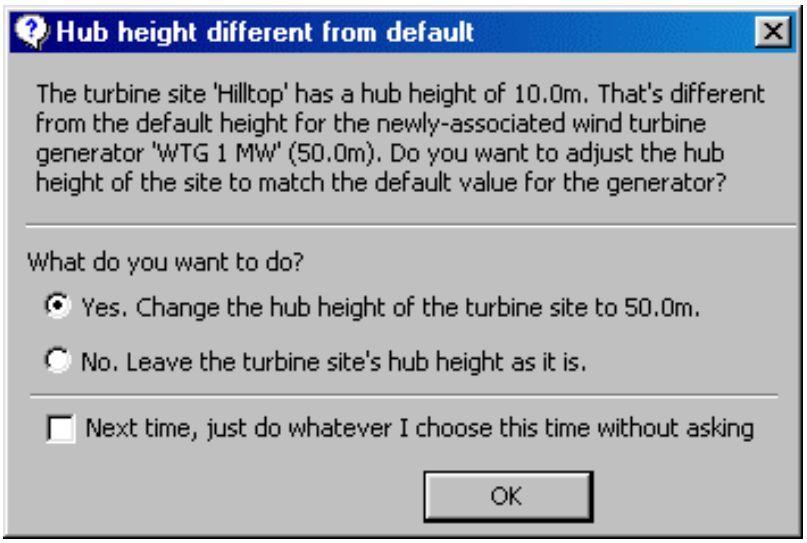



If you want to adjust the location of the site to an exactly specified position, then use the site dialog box, which can be reached at any time from the right-click menu of the turbine site icon in the workspace hierarchy by choosing Show. You can also call up the dialog box by right-clicking on the turbine site icon in the map.

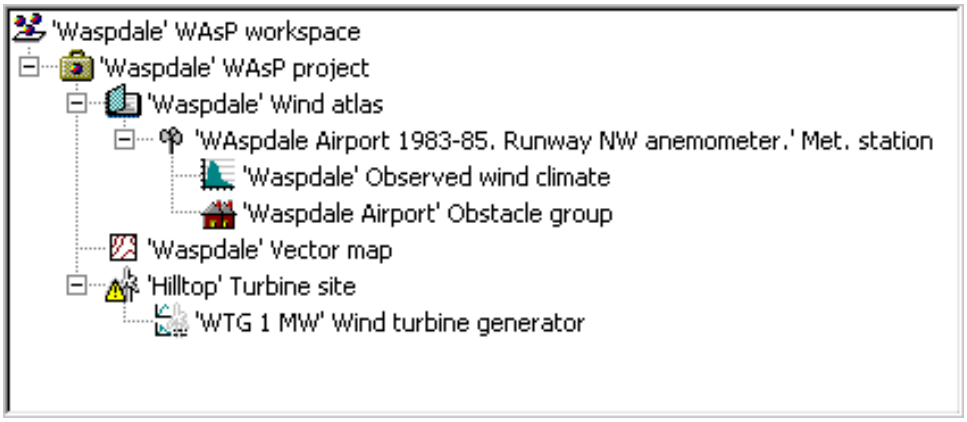
### Assigning the power curve

In order to predict how much power will be produced by the turbine, WAsP needs to know the power production characteristics of the turbine. You provide this information to WAsP by associating a wind turbine generator hierarchy member with the turbine site. From the turbine site's right-click menu, select Insert from file, and then choose 'Wecs1000.pow' when prompted.

Since the hub height is different from the default prediction height (10 m a.g.l.) WAsP will ask you what to do:




Press Ok to change the prediction height to the actual hub height. The hierarchy should now look like this:

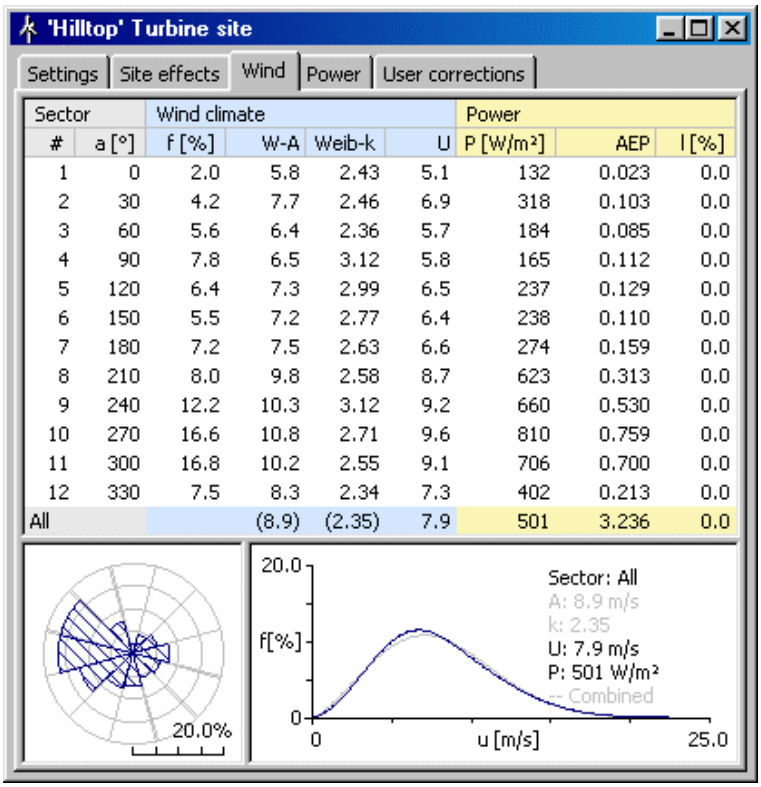



Open the power curve window (right-click and Show) to view the generating characteristics of the turbine.

### Predicting the wind climate

WAsP is now ready to predict the wind climate at the turbine site. From the turbine site's right-click menu, select Calculate site effects, PWC and AEP for turbine site. As with the met. station, the small yellow warning sign at the turbine site icon disappears as soon as the calculation is performed.

You can now open the turbine site window to view the results. Right-click the turbine site, choose Show and then click on the Wind or Power tab:




The mean wind speed at the turbine site is 7.9 $ms^{-1}$ and the predicted power production 3.236 GWh.

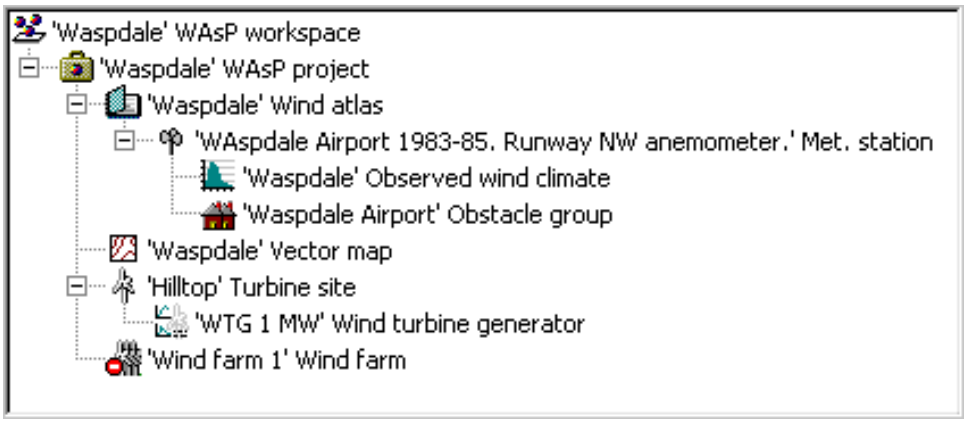
The numbers shown above might differ slightly from those returned to you, because the location of the sites might not be exactly the same. WAsP has estimated that about 2.6 GWh per year would be generated by erecting a turbine on the hilltop. This number is referred to as the Annual Energy Production (AEP).

You can now return to the *Friends of Wind Energy, Waspdale Ltd.* and make your report!

### 3.3.6 Establishing a wind farm

#### Setting up a wind farm

You need to add a wind farm hierarchy member to the workspace. Insert a new wind farm as a child of the project. The workspace now looks like this:




Provide a name for the wind farm by right-clicking the wind farm icon and choose Rename. Call it 'Crest', since the plan is to establish the wind farm along the hill crest. Next, you need to insert turbine sites to the wind farm.

WAsP now requires:

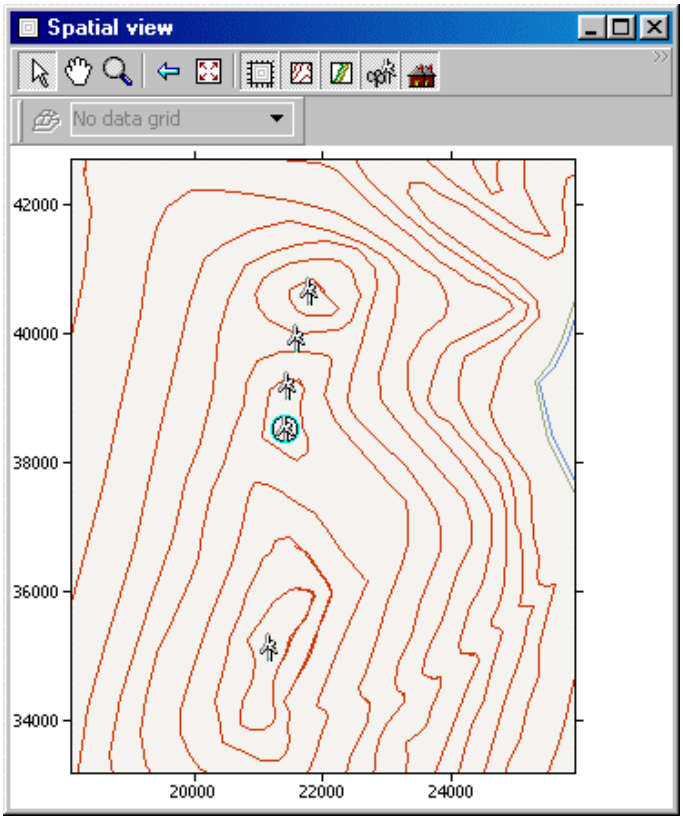
- the locations of wind farm turbine sites in the map
- a description of the type of wind turbine that you propose to use

There are still no obstacles near the hilltop, so there is no need to add an obstacle list to this wind farm.

**Locating the turbine sites**

First, right-click the wind farm hierarchy member and select Insert new, then choose Turbine site. Next, move this new turbine site to a location on the hill crest (say, north of the existing turbine site) as was described in the previous section (here).

It is possible to add more turbines to the wind farm in the following simple way: choose the first turbine site by left-clicking it (a small ring appears around the turbine), hold the left-hand mouse key and the Ctrl-key on the keyboard down while dragging the turbine site to a new location, release the left-hand mouse button... You have now created a new wind turbine site in the wind farm. Add two more wind turbines; the spatial view should now look something like this:

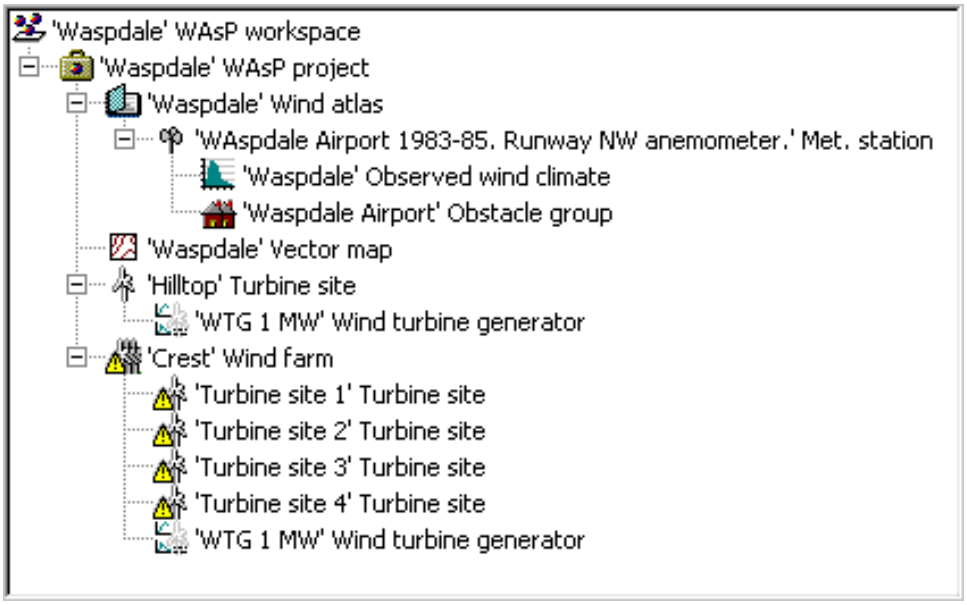



If you want to adjust the location of the sites to exactly specified positions, then use the site dialog box, which can be reached at any time from the right-click menu of the turbine site icon in the workspace hierarchy by choosing Show. You can also call up dialog boxes by right-clicking on each of the turbine site icons in the map.

**Assigning wind turbine generators**

In order to predict how much power will be produced by the wind farm, WAsP needs to know the power production and thrust curve characteristics of each turbine. If the turbines in your farm are all of the same type, you provide this information to WAsP by associating a wind turbine generator hierarchy member with the wind farm. From the wind farm's right-click menu, select Insert from file, and then choose 'Wecs1000.pow' when prompted.

The hierarchy should now look like this:

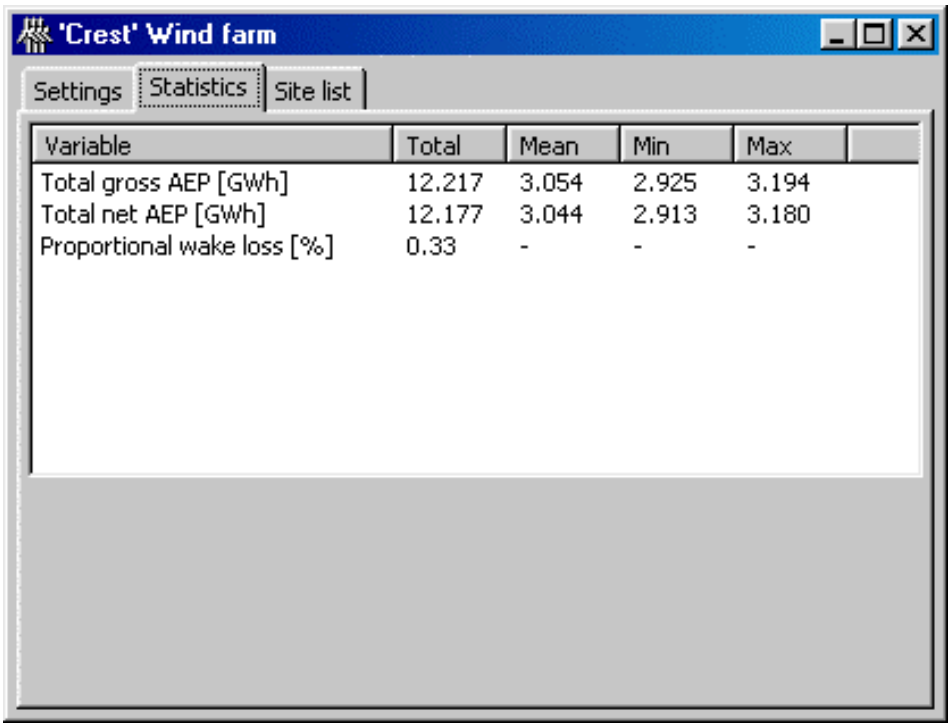



If one or more turbines in a farm are different from the rest, you must provide a separate wind turbine generator hierarchy member for this or these turbine. In this case, the wind turbine generator characteristics are inserted as a child of the turbine site(s), just like you did with the 'Hilltop' site.

**Predicting wind farm production**

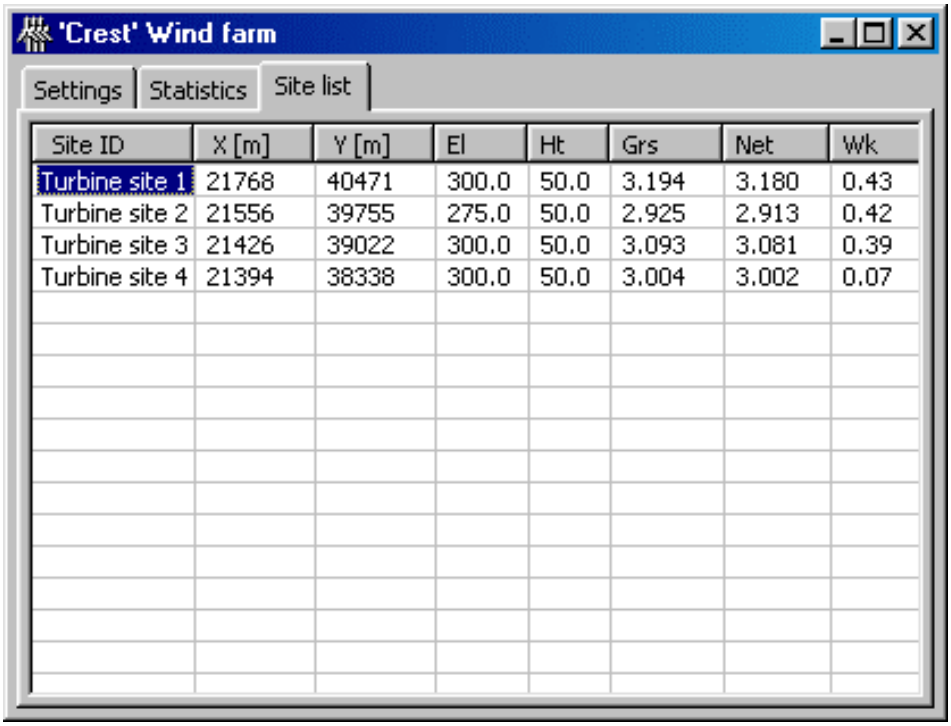
WAsP is now ready to predict the power production of the wind farm. From the wind farm's right-click menu, select Calculate data and wake losses for wind farm. As with the met. station, the small yellow warning signs at the turbine site and wind farm icons disappear as soon as the calculation is performed.

You can now open the turbine site window to view the results. Right-click the turbine site, choose Show and then click on the Statistics tab:



The predicted power production of the wind farm is 12.2 GWh. The wake effects are very small here because the wind farm consists of one row of turbines at right angles to the prevailing wind direction. The numbers shown above might differ slightly from those returned to you, because the location of the sites might not be exactly the same.

More details are available in the 'Site list' tab: the exact location of the turbine site, the elevation, the hub height, the gross and net power production and the wake loss.




| Site ID | X [m] | Y [m] | El | Ht | Grs | Net | Wk |
|---|---|---|---|---|---|---|---|
| Turbine site 1 | 21768 | 40471 | 300.0 | 50.0 | 3.194 | 3.180 | 0.43 |
| Turbine site 2 | 21556 | 39755 | 275.0 | 50.0 | 2.925 | 2.913 | 0.42 |
| Turbine site 3 | 21426 | 39022 | 300.0 | 50.0 | 3.093 | 3.081 | 0.39 |
| Turbine site 4 | 21394 | 38338 | 300.0 | 50.0 | 3.004 | 3.002 | 0.07 |

More details about the wind climate etc. are available in each turbine site's Show window.

## 3.4 There's a lot more to learn...

There's still a lot more to learn about the user interface of WAsP, but as you have seen, you don't need to know about that in order to get work done. For first-time WAsP users, it's important to understand more about what WAsP is actually doing behind the scenes. WAsP results are not useful unless the models' limitations are understood. Before using WAsP for any real world applications, it's important to study the material, which explains WAsP modelling in more detail.

The Modelling with WAsP book of this help facility offers brief explanations to many aspects of the wind atlas methodology. For more comprehensive descriptions you should consult the Risø readings on wind power meteorology, in particular the European Wind Atlas. Details on specific topics may also be found in the publications in the References section.

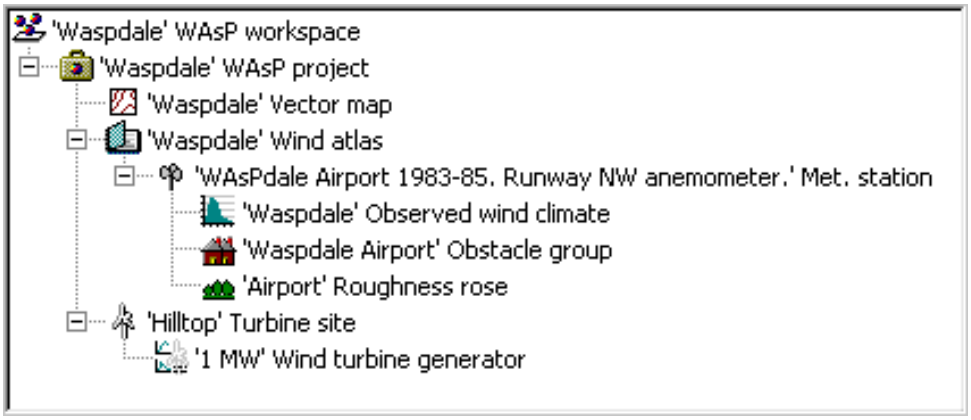
## 3.5 Sample data and workspaces

In addition to the sample data used for the Quick Start Tutorial, three sample workspaces are installed in the folder 'C:\Program Files\Wasp\Sample data\Wasp workspaces' during the installation: 'WAsPdale', 'WindFarmer' and 'ResourceGrid'. You may Open any of these workspaces and study how typical WAsP applications are set up in the workspace hierarchy.

A collection of sample wind turbine power curves are installed in the folder 'C:\Program Files\Wasp\Wind turbine generators'. These are also available directly from the WAsP Library.

### 3.5.1 Sample workspace #1: Waspdale

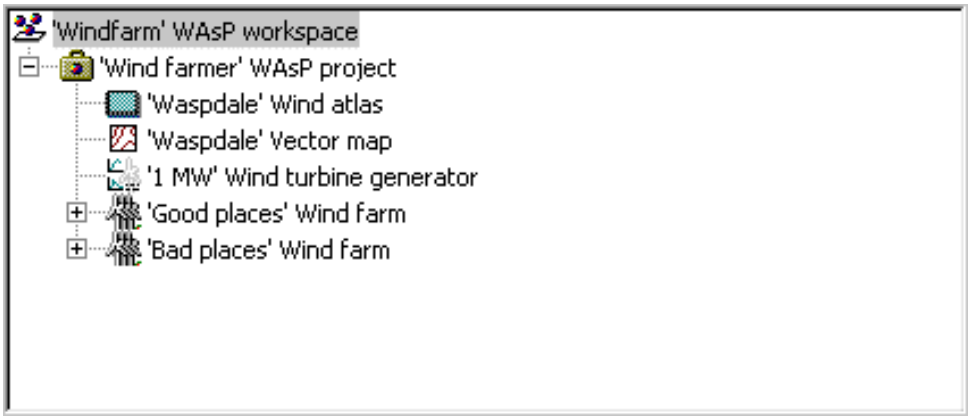
The 'Waspdale' workspace is an example of the classic WAsP session: analysing the wind data from a met. station to obtain the regional wind climate (wind atlas) and then using the same wind atlas data set to predict the wind climate and power production at a nearby turbine site:




Note, that both the met. station and the turbine site are located in the same map; this is typical, but not necessary. The regional wind climate is assumed to be the same at both sites.

### 3.5.2 Sample workspace #2: Windfarm

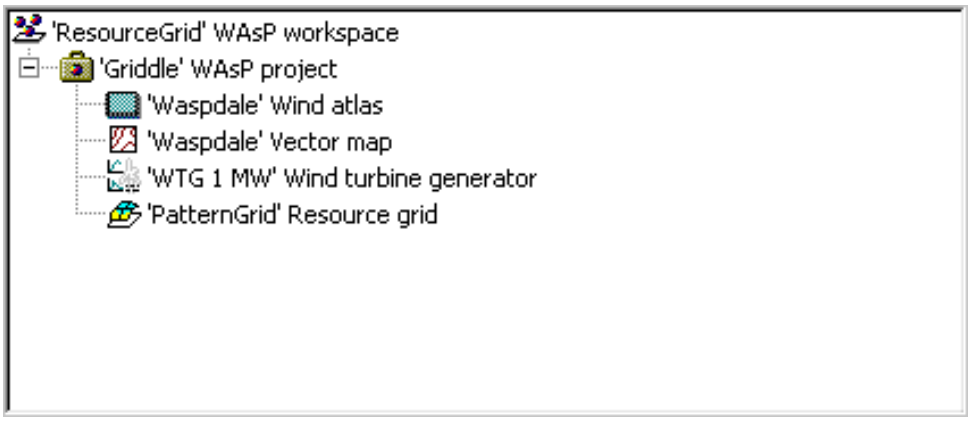
The 'Windfarm' workspace is an example of another typical application: an existing wind atlas data set is used to predict the power production of several wind farms (or different layouts) in a given area:




Note, that the wind atlas, map and power curve are common to both wind farms.

### 3.5.3 Sample workspace #3: ResourceGrid

The 'ResourceGrid' workspace is an example of how to investigate the variation in the wind resource over an area: an existing wind atlas data set is used to predict the wind climate and power production of several wind turbine sites in a given area:

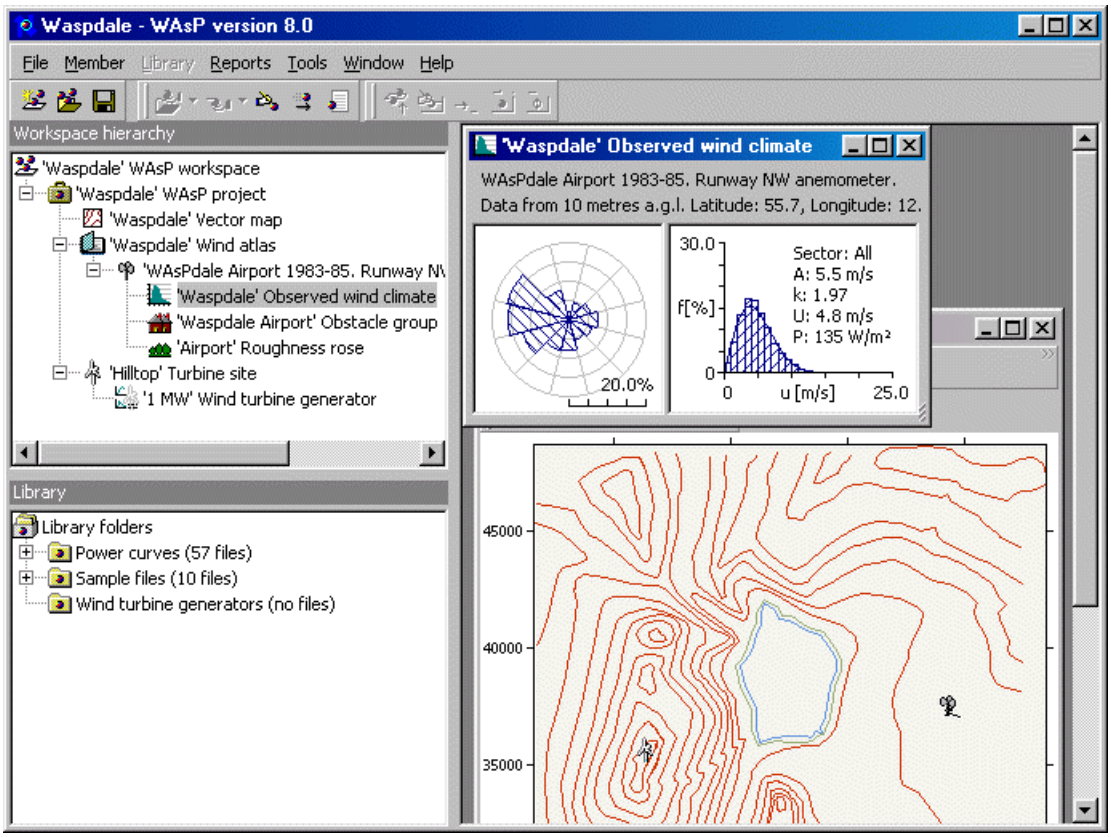



Again, the wind atlas, map and power curve are common to all the modelled wind turbine sites. The turbine sites are arranged in a regular grid and the resource grid can be used to establish a wind speed or power production map of the area – suitable for micro-siting of the actual turbine sites in a wind farm.

# 4 WAsP User's Guide

## 4.1 The WAsP user interface

### 4.1.1 Overview of the WAsP user interface




The main window of WAsP has four work areas.

At the top of the main window lies the application menu and toolbars. These can be moved to new positions.

On the left hand side of the main window are two panes: the workspace hierarchy pane and the library pane. These cannot be moved or closed, but they can be re-sized. The workspace hierarchy pane and the library pane are only visible when a workspace is currently open in WAsP.

The remaining space in the main window is the window area. This space is used to display windows, which can be opened, moved, resized and closed while working with the program.

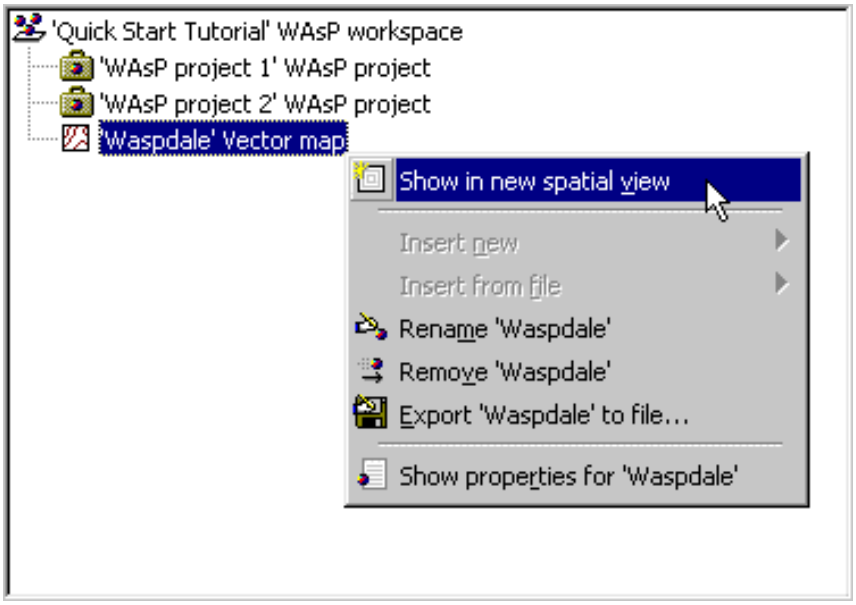
Related Topics

### 4.1.2 Use the right-hand mouse button!

Working with menus and the keyboard is not the quickest way to get things done in WAsP. Whatever you are doing, try clicking with the right-hand mouse button and see what happens. Often there is a handy context-sensitive pop-up menu, which will contain the very command you need.

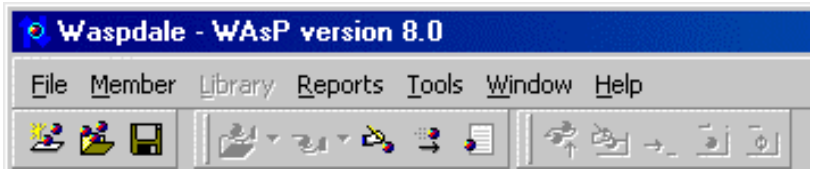
So if you want to view a map, don't go to the main menu and look for a nested sub-menu

called 'Display' with a massive list of all the things that could ever be done or displayed. Instead, click on the map's icon with the mouse and then hit the right-hand mouse button:




### 4.1.3 Menu and toolbars

WAsP has a main menu and three toolbars:




**The main menu**

The main menu contains the following sub-menus:

**File**. Lets you open, save and close workspaces.

**Member**. A context-sensitive menu, which lets you call the methods of the currently selected hierarchy member.

**Library**. A context-sensitive menu, which lets you perform operations on the library.

**Reports**. A context-sensitive menu, which lets you call the report generator for the currently selected member.

**Tools**. A list of launchable utility programs, scripts, import operations and some user options.

**Window**. A menu to help you manage the windows which are currently open.

**Help**. Information about WAsP: help file, WAsP on the Web, etc.

The Member, Library and Reports sub-menus are sometimes disabled, depending on the what part of the program you are using.

**The toolbars**

Each toolbar contains buttons, which correspond to the most frequently-used items accessible from the sub-menus of the main menu: the workspace toolbar, the member

toolbar, the library toolbar. The toolbars can be moved around or closed. WAsP will remember the way that you organise the toolbars between runs.

### 4.1.4 WAsP workspaces

In WAsP, all work is performed within the context of a workspace. Workspaces can be created, saved and re-opened. When you start WAsP, you need to re-open or create a workspace before you can do any work.

A workspace contains one or more projects and may contain members (data files) that are not used in any project. The data files at the workspace level are thus not used for any calculations in any projects.

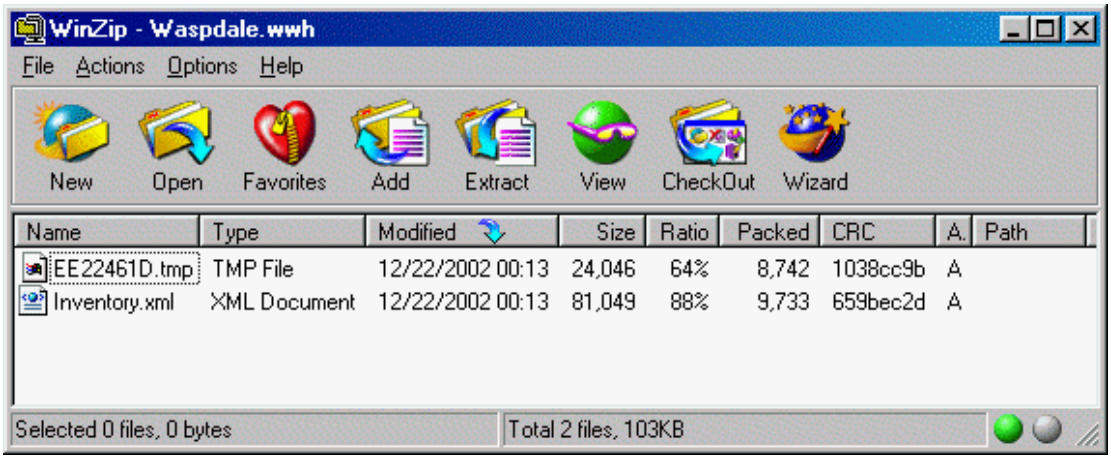
Workspaces are saved as single files, which have the extension 'wwh'. A workspace file contains the workspace data in a single ZIP archive. These files are small, self-contained, and guaranteed to be complete. A copy is a copy, so backing up is easy.

When a file is imported to WAsP to add a member to the hierarchy (for example a map or wind atlas), the data are copied into the workspace, and the original data file is thereafter independent. WAsP remembers where the file came from and every time a workspace is opened, the previously imported files are checked. If they're still where they originally were, and if their data have been updated since they were imported, then you get a warning and an opportunity to re-import them.

**The workspace file**

The workspace zip file contains simply zipped data files for large discrete lumps or data (map files and resource grid results) as well as an XML file called the inventory. The inventory includes most of the data from the workspace, saved in XML format.

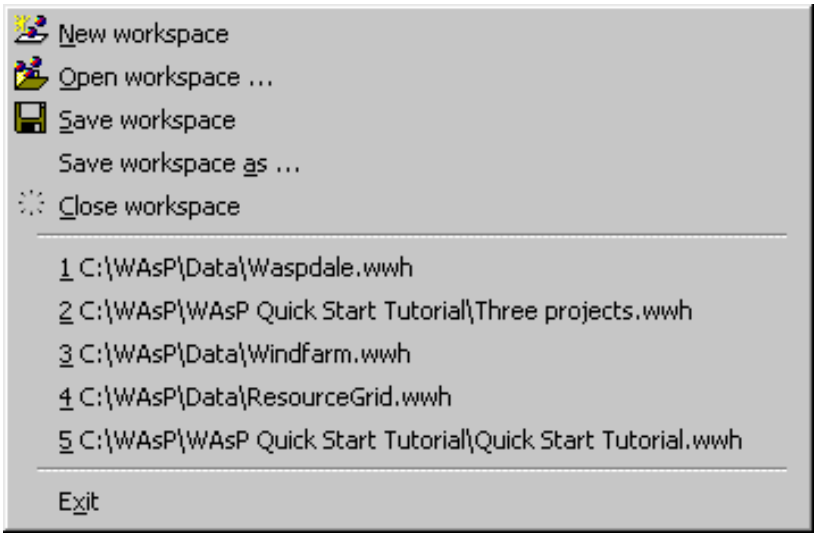
Here's a WAsP hierarchy file (it can be used to save any part of a hierarchy, such as a project). You can just open them in WinZip to see what's inside.




The *.tmp file there is just the map. You can extract it to disk and it's just the same as a standard WAsP map file. The inventory XML file can also be extracted and viewed in Internet Explorer, for example. Here's a screen capture showing the Waspdale workspace inventory. For readers unfamiliar with reading XML in Internet Explorer, note that the little plus and minus signs indicate an expandable/collapsable tree. There's a lot of data there buried in the depths of the file.

### 4.1.5 Working with workspaces

The File menu can be used to create, open, save and close workspaces:




The menu also includes a list of the most recently used workspaces.

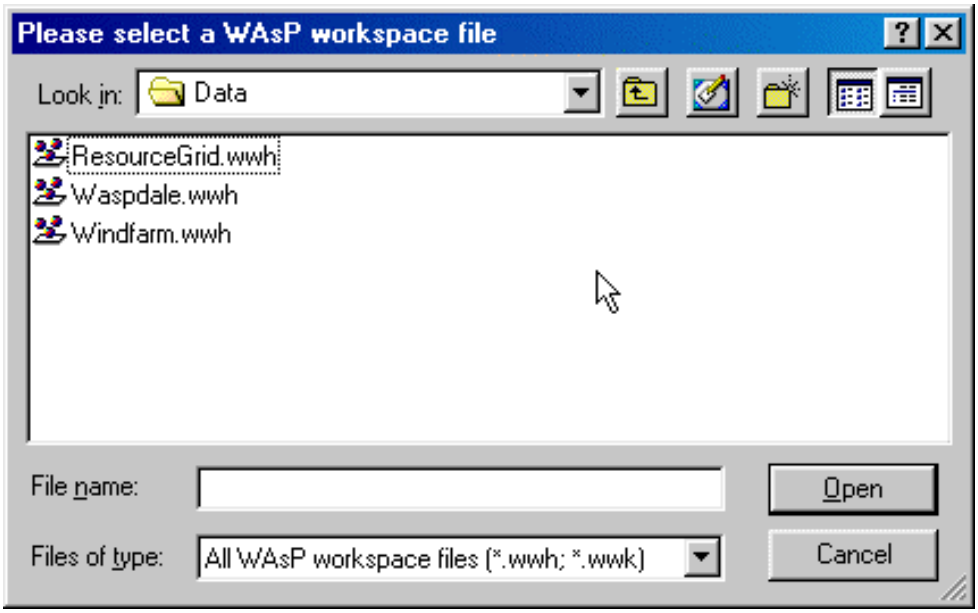
There is a workspace toolbar, which offers the main workspace functions:

**Saving an existing workspace**

Use Save workspace or Save workspace as from the File menu. The workspace and all its contents will be saved to file.

**Opening an existing workspace**

To open a workspace, simply use Open workspace from the File menu and select the workspace file (*.wwh) itself using the standard file dialog box.



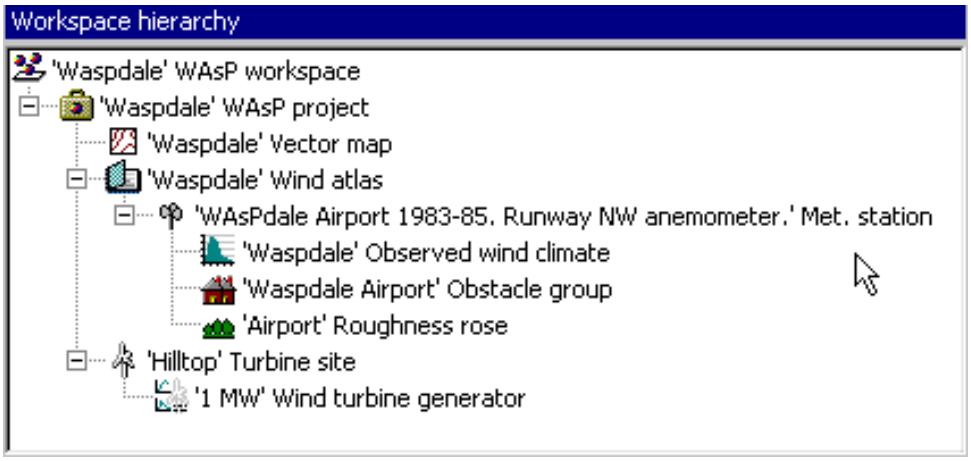
## 4.2 The workspace hierarchy

### 4.2.1 About the workspace hierarchy

When a workspace is open in WAsP, the contents of the workspace are organised into a hierarchy. The items in the hierarchy are called hierarchy members, or just members if the context is clear. The generic symbol for a hierarchy member is a small coloured ball  .

The hierarchy is visually represented in a hierarchical tree, rather similar to the one used in Windows Explorer. Each member is represented by an icon and some text. The tree is called the workspace hierarchy, or just hierarchy if the context is clear.

Here's an example:




At the top of the hierarchy is the workspace root. Members can be parents and children of one another. Two members which share the same parent are called siblings, or peers. The workspace root cannot have a parent, but all other members always have a parent.

**The hierarchy defines the modelling scenario**

The organisation of the members in the hierarchy forms associations between the members. The members and their associations together represent a description of the situation, which is being modelled. Work in WAsP is done by adding, removing, moving and manipulating hierarchy members to change the modelled situation.

The hierarchy enforces rules governing the possible parent-child associations between different types of hierarchy member. Some types of member can never be children of some other types of member, and some types of member cannot have children at all.

When working in WAsP, all significant modelling tasks must be done in a project, not a workspace. A project is a modelling environment. The workspace area is a scratch area, or a way of working with several projects at the same time.

Related topics  Working with...  Learn more...

### 4.2.2 What is a hierarchy member?

**Members and their files**

The WAsP models need data files for input and output. Most hierarchy members represent WAsP data files on the computer's file system. Members can be thought of as copies of these files; the hierarchy's purpose it to represent modelling relationships between the members. The organisation of members in the hierarchy is not related to the arrangement of their corresponding data files on the computer's file system.

Members can be:

- inserted into the hierarchy as new
- inserted into the hierarchy from file
- saved or exported to file
- saved to a file with a different name
- removed from the hierarchy

When WAsP works with hierarchy members, nothing is written to the members' original file contents until the changes are explicitly exported. This is because WAsP works with copies of the data files or, for some hierarchy members, simply holds all the information in memory.

When a member is removed from the hierarchy, the corresponding file (from which is was inserted) is not deleted from the file system.

**Different members, different rôles**

Some members preserve information about the arrangement of their children. When these members are re-opened, they automatically re-open all of their children into the workspace too. The workspace root itself is one such member, so when a workspace is re-opened, all of the members which were in the workspace the last time it was saved will be re-opened and their relationships restored. Projects also preserve information about their children between runs.

Other members are largely responsible for holding data, and do not preserve information about the organisation of the hierarchy. These hierarchy members have windows which can be opened in the right hand side of the main window, allowing their data to be viewed and, in some cases, manipulated.

### 4.2.3 Introducing the hierarchy members

There are several types of hierarchy member, which can appear in the workspace. The list below provides a brief introduction to them. They are explained in more detail elsewhere.

 Workspace root

There is always one (and only one) root in each workspace. It sits at the top of the hierarchy and has no parent. The workspace root can have members of any type as its children. When a previously saved workspace is opened, all of the children of the workspace are also re-opened.

 Project

Projects are used to manage related groups of hierarchy members. Projects offer several facilities, which make it easy to perform operations that are relevant to all of the members of the project. Projects are always children of the workspace root. When a previously saved project is opened, all of the children of the project are also re-opened, so entire projects can be saved and used in other workspaces.

 Vector map

WAsP uses vector maps to get information about the orography and roughness characteristics of the landscape in which the modelling is being done. Maps can appear in various places in the workspace hierarchy, but typically each project will have one map.


Wind atlas (regional wind climate)

Wind atlases (or regional wind climates) are the central members in the hierarchy. A WAsP wind atlas contains data describing a site-independent characterisation of the wind climate for an area. The WAsP models are devoted to analysing wind data collected from met. stations to produce wind atlases and applying the atlas to estimate the wind climate (and power production) for turbine sites.

A wind atlas is illustrated using a closed book icon if the atlas is simply a static data file. An open book icon is used if the wind atlas is associated with a met. station which might re-calculate and thereby change the atlas.


Met. station

A meteorological station (met. station for short) is used to calculate a wind atlas. It represents a data collection site located somewhere in an associated map. A met. station does not have any data except its location in the map and user-specified corrections. It is associated with a wind climate which has been observed at the station. It may be associated with a list of obstacles surrounding the station and a description of the roughness lengths of the surrounding area.

A set of user corrections can be associated with a met. station. It provides a way of informing WAsP about some site-specific adjustments which cannot be described using the other hierarchy members.


Observed wind climate

A summary of the wind data recorded at a met. station is called an observed wind climate (or OWC for short).


Turbine site

A turbine site is used to estimate the power production which would result from locating a turbine somewhere in an associated map. A turbine site does not have any data except its location in the map, the hub height of the turbine and user-specified corrections. A turbine site may be associated with a list of obstacles surrounding the station and also a description of the roughness lengths of the surrounding area.

A set of user corrections can be associated with a turbine site. It provides a way of informing WAsP about some site-specific adjustments which cannot be described using the other hierarchy members.


Wind farm

Wind farms are collections of turbine sites which are calculated in a batch. Wind farms offer a convenient way to work with several sites together. In addition to estimates of the wind climate and power production of the wind farm and wind turbines, the wind farm member also holds information about the wake losses in the wind farm.


Resource grid

Resource grids are collections of 'light-weight' turbine sites calculated in a batch, but here the sites are arranged in a regular grid covering an area. The extension of the grid and the grid cell size may be chosen to map the wind climate or wind resource anywhere in the map – and with as much detail as is required.


Wind turbine generator

A wind turbine generator member describes the way that a turbine's power output changes

with wind speed and also the thrust characteristics of the wind turbine. It can be associated with one or many turbine sites or wind farms.

Obstacle group

Met. stations and (less commonly) turbine sites can have sheltering obstacles in their surroundings. An obstacle group is a description of some sheltering obstacles which can be associated with a site.

Roughness rose

An alternative to providing roughness information in a map is to provide a site-specific, sector-wise description. Turbine sites and met. stations can both be associated with roughness descriptions.

### 4.2.4 Modelling with the hierarchy members

WAsP modelling involves:

- analysing observed wind data to calculate regional wind climates (wind atlases) and
- applying wind atlases to particular turbine sites to calculate an estimate of the wind climate and power.

In the workspace hierarchy, these calculation jobs are performed by met. stations, turbine sites, wind farms and resource grids.

**Met. stations are used to calculate wind atlases**

A wind atlas is calculated by adjusting a summary of recorded wind data to remove the influencing effects of the collection site itself. To calculate a wind atlas, a met. station uses the following hierarchy members:

an observed wind climate

the map in which the met. station is located

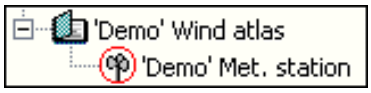
(optionally) a list of the obstacles surrounding the data collection site

(optionally) a description of the surface roughness for the area surrounding the site

In summary, uses + + + to produce

The met. station may (optionally) contain a set of user corrections to apply to the summary data.

Met. stations are always children of the atlases which they are calculating, and so the output is 'moved up' the hierarchy into the parent atlas, thus:




**Turbine sites are used to calculate predicted wind climates**

A predicted wind climate is calculated by adjusting the data from a wind atlas for the influencing effects of the turbine site itself. To calculate a predicted wind climate, a turbine site uses the following hierarchy members:

a wind atlas

the map in which the turbine site is located

(optionally) a power/thrust curve describing the turbine's generating characteristics

(optionally) a list of the obstacles surrounding the turbine site

(optionally) a description of the surface roughness for the area surrounding the site

If no power curve is used, then the output will be simply a predicted wind climate which describes wind directions, speed and energy.

In summary, uses + + + to produce

The turbine site may (optionally) contain a set of user corrections to apply to the wind atlas data.

**Wind farms are used to calculate power production for several sites**

Wind farms calculate summary wind climate data for each of several turbine sites by adjusting the data from a wind atlas for the influencing effects of the turbine sites itself. To calculate the summary data, a wind farm uses the following hierarchy members:

a wind atlas

the map in which the wind farm sites are located

one or more power/thrust curves describing the generating characteristics of the turbines

In summary, uses + + to produce summary data displayed by .

**Resource grids are used to calculate power production for a grid of sites**

Resource grids calculate summary wind climate data for each of several sites by adjusting the data from a wind atlas for the influencing effects of the sites itself. To calculate the summary data, a resource grid uses the following hierarchy members:

a wind atlas

the map in which the resource grid is located

a power curve describing the generating characteristics for the resource grid

In summary, uses + + to produce summary data displayed by .

**Wind farms and resource grids appear less often in the help**

It is obvious that (in terms of the hierarchy interactions) the wind farm and resource grid calculations are a simpler subset of the turbine site calculations. To simplify the documentation, they are often ignored when explaining general modelling issues. The explanations focus on the met. stations and the turbine sites. It's generally safe to assume that wind farms and resource grids can be treated as turbine sites which have no children in the hierarchy.

### 4.2.5 Patterns of association

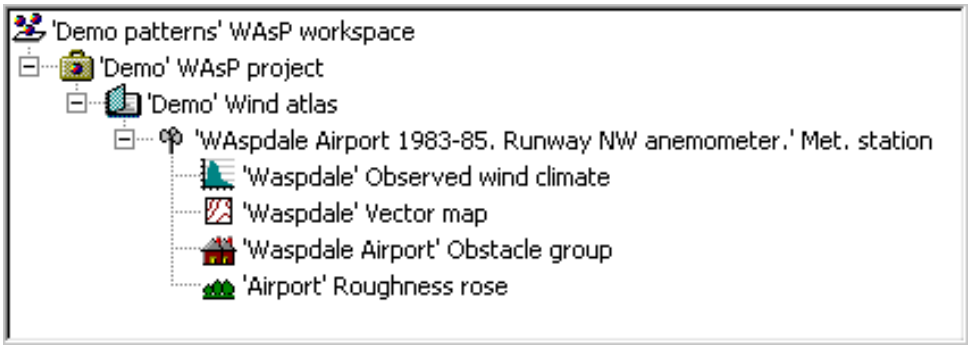
The organisation of the members in the hierarchy forms associations between the members.

The associations are only important to members that perform calculations: met. stations, turbine sites, wind farms and resource grids. In order to perform their calculations, these members need to work out which other members to use. The calculating members seek to assemble a correct set of other members.

**Simple associations**

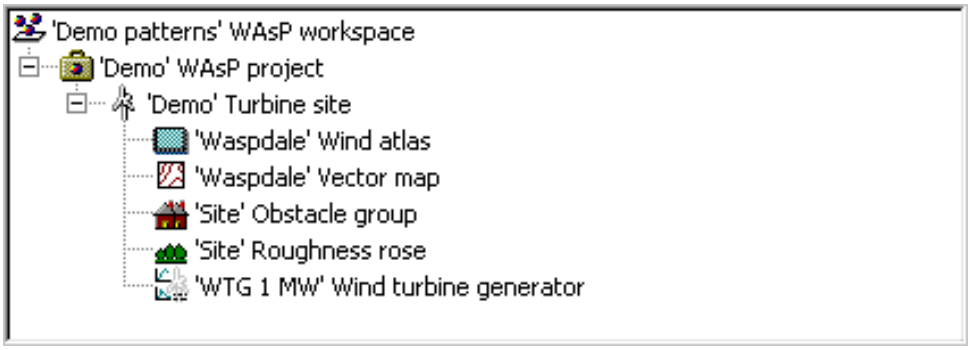
The simplest kind of association is the parent-child association. A calculating member can simply have all of the necessary members as its children.

For a met. station's calculation, the associated members could be organised thus:

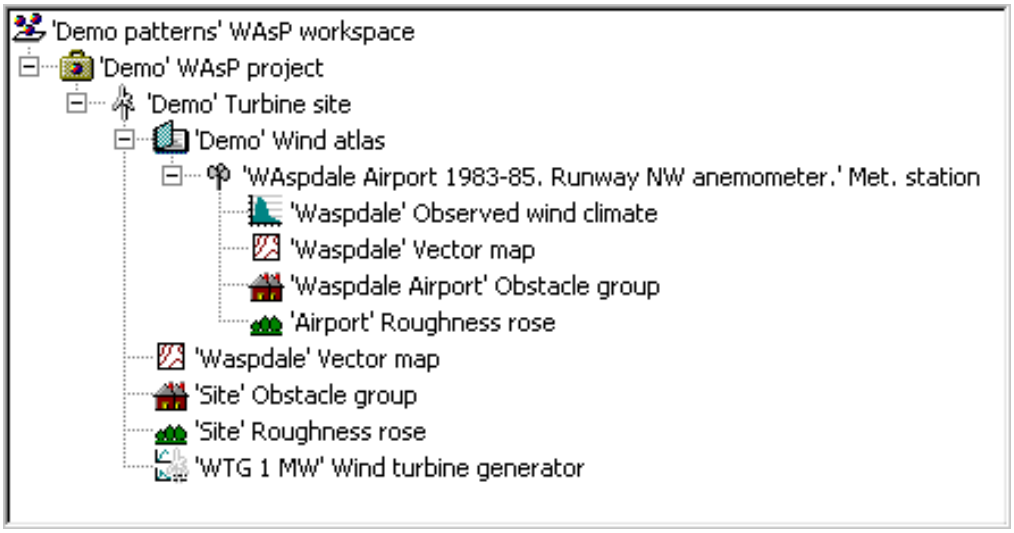



Note, that the met. station is a child of the wind atlas which it is calculating. This is always the case, since output from met. stations 'moves up' the hierarchy.

For a turbine site's calculations, the associated members could be organised thus:




Note, that the wind atlas being used is just a static data file (the closed book icon is displayed). If the wind atlas was dynamically calculated from a turbine site, the workspace could look like this:

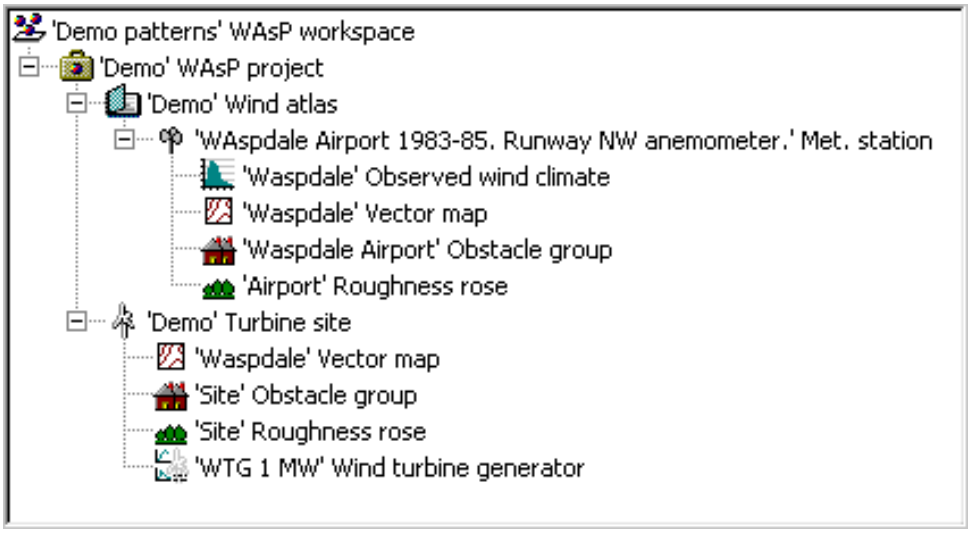



The arrangement illustrated above would work perfectly well, but it is rather inelegant. The same map appears twice in the project. If a new turbine site was added to the project, then the wind atlas would need to be added to that turbine site too. It's possible to take advantage of more complex associations to simplify the hierarchy and to make it easier to add new sites to the project.

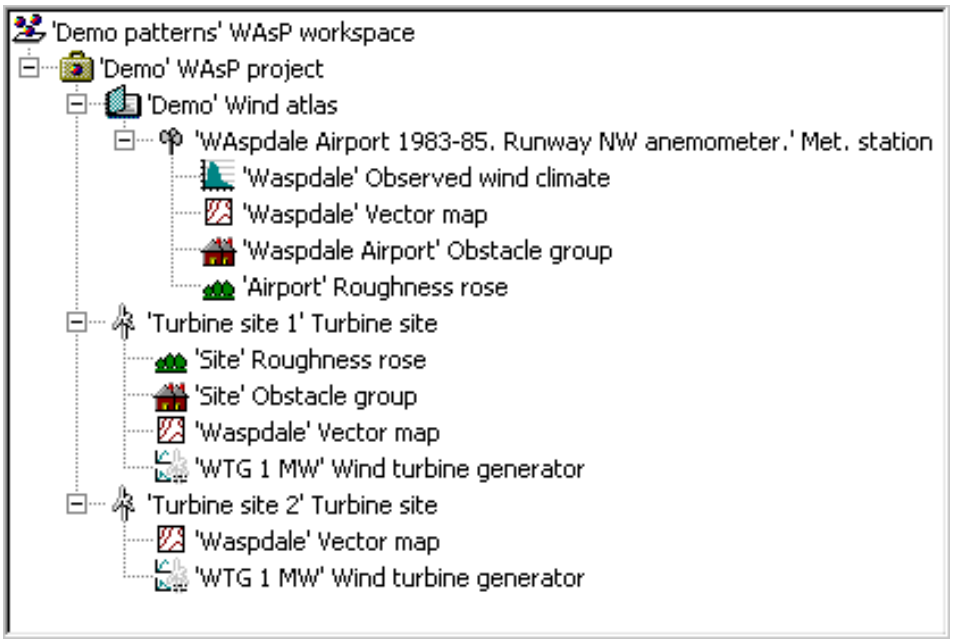
**More complex associations**

Members are associated if they have a parent-child association, but members can also explore further up the hierarchy in search of associations. Any ancestor (parent's parent, etc.) can be treated as associated, as can peers of any ancestor. This system allows a modelling situation with many relationships to be expressed concisely.

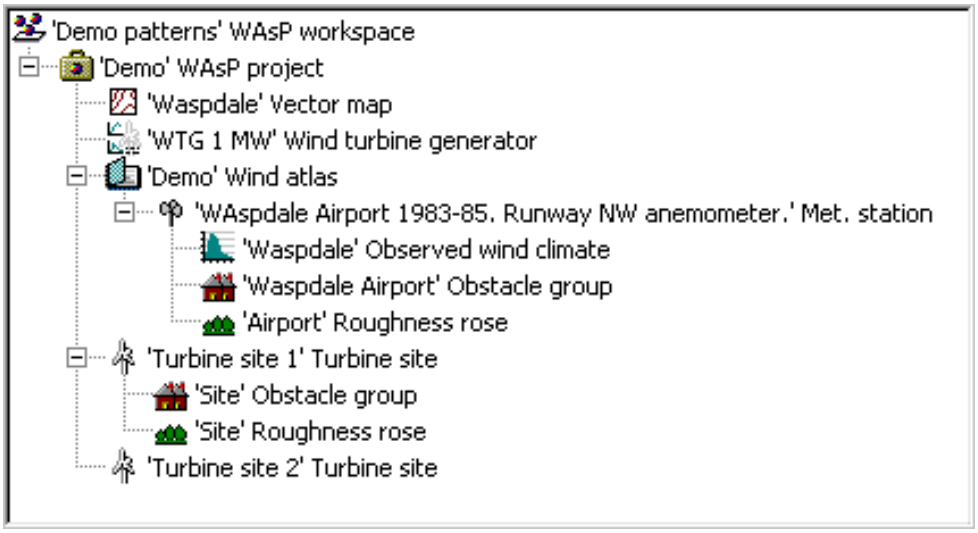
Working with the example given above, the hierarchy could be re-organised so that the wind atlas and the turbine site are peers, like this:




Modelling output is moving up the hierarchy because the met. station is writing results to the atlas and along the hierarchy because the atlas and the turbine site are peers. This pattern allows more turbine sites to be added to the project without needing to replicate the atlas, as follows:

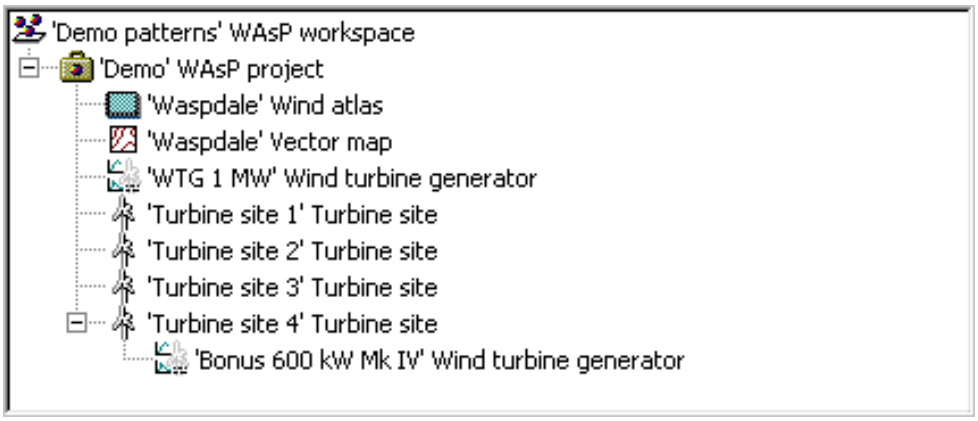



In the hierarchy illustrated above, the same map appears in three places. By making the map a peer of the turbine sites and wind atlas, it can be shared by the turbine sites and the met. station. The same power curve also appears twice. It, too, can be made a peer of the two turbine sites and can then be used by both of them, thus:




It is not possible for sites to share site-specific information, such as obstacle lists and observed wind climates which by definition are unique to the site itself.

If a member is associated with more than one member of the same type, then the nearest relative is the one used. This allows a group of peers to use the same member, but one or more of them can use a different member. For example, several turbine sites could be using the same power curve but one of them could use a different type, as shown in the hierarchy illustrated below:




The first three turbine sites will all use the 'M450_150' power curve, but the 'Yet another' turbine site will use the 'M350_175' power curve.

### 4.2.6 Legitimate parent-child associations

The table below specifies the how parent-child associations can be formed between different types of hierarchy members. There's no need to remember or refer to this table when using the software, because the hierarchy members themselves automatically enforce these rules.

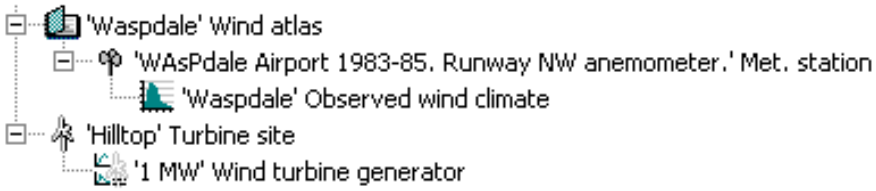
| Object type | Valid parents | Valid children (and number) |
|---|---|---|
| Workspace root | None | Any (0..n) |
| Project | Workspace | Wind farm (0..n)<br>Resource grid (0..n)<br>Turbine site (0..n)<br>Obstacle group (0..1)<br>Map (0..1)<br>Atlas (0..1)<br>Wind turbine generator (0..1) |
| Wind farm | Workspace<br>Project | Map (0..1)<br>Atlas (0..1)<br>Obstacle group (0..1)<br>Wind turbine generator (0..1) |
| Resource grid | Workspace<br>Project | Map (0..1)<br>Atlas (0..1)<br>Wind turbine generator (0..1) |
| Turbine site | Workspace<br>Project<br>Wind farm | Roughness description (0..1)<br>Obstacle group (0..1)<br>Map (0..1)<br>Atlas (0..1)<br>Wind turbine generator (0..1) |
| Map | Workspace<br>Project<br>Wind farm<br>Resource grid<br>Turbine site<br>Met. station | None |
| Atlas | Workspace<br>Project | Met. station (0..1) |

| | | |
|---|---|---|
| | Wind farm<br>Resource grid<br>Turbine site | |
| Met. station | Workspace<br>Atlas | Observed wind climate (0..1)<br>Roughness description (0..1)<br>Obstacle group (0..1)<br>Map (0..1) |
| Observed wind climate | Workspace<br>Met. station | None |
| Roughness description | Workspace<br>Turbine site<br>Met. station | None |
| Obstacle group | Workspace<br>Project<br>Wind farm<br>Turbine site<br>Met. station | None |
| Wind turbine generator | Workspace<br>Project<br>Wind farm<br>Resource grid<br>Turbine site | None |

### 4.2.7 Associated members have the same number of sectors

The WAsP models represent the world in sectors. The number of sectors used for the modelling is not fixed but data structured with 8 sectors is of course incompatible data structured with 12 sectors. So, all associated hierarchy members which are being used together for modelling must have the same number of sectors.

The number of sectors used is determined by the structure of the observed wind climate, since this feeds directly into the wind atlas and then on through the turbine sites to determine the structure of the predicted wind climates:




The number of sectors in an observed wind climate is determined when it is first generated from raw data using the OWC Wizard.

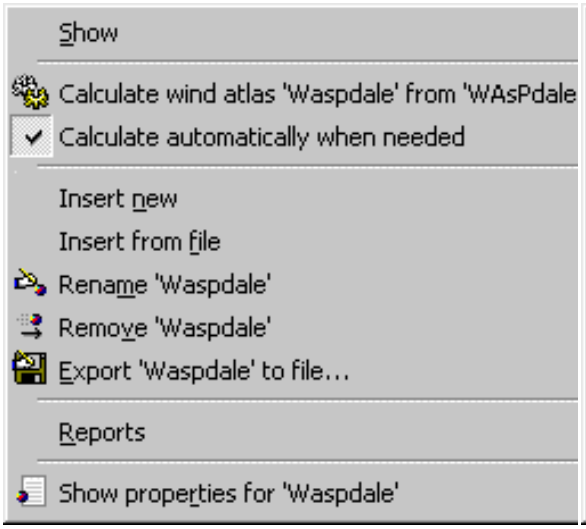
# 4.3 Working with the hierarchy

### 4.3.1 Hierarchy members' methods

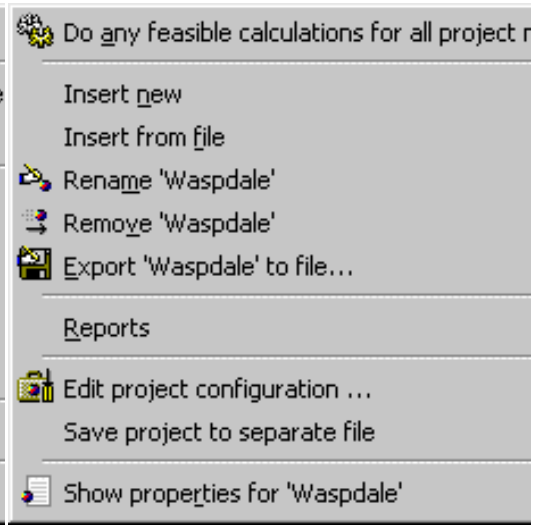
## The member's menus

Each hierarchy member has a menu of commands, or methods. This menu is headed Member and appears as a sub-menu of the main menu. It further appears as a pop-up menu if a member is clicked with the right mouse button.

This menu is the most important tool for working with WAsP. Depending on which hierarchy member is selected, the contents of the menu presented will be different. Some members do not offer all of these methods, and some offer extra methods in addition to those shown. The illustration below shows a basic member's menu (for a wind atlas) and a project members menu.




Wind atlas member's menu




Project member's menu

# 4.4 The members' toolbar

There is also a hierarchy member toolbar which offers buttons for some of the most common hierarchy member methods:

The buttons (from left to right) correspond to the menu items Insert from file, Insert new, Rename, Remove and Show properties.

# 4.5 Viewing a member's interface window

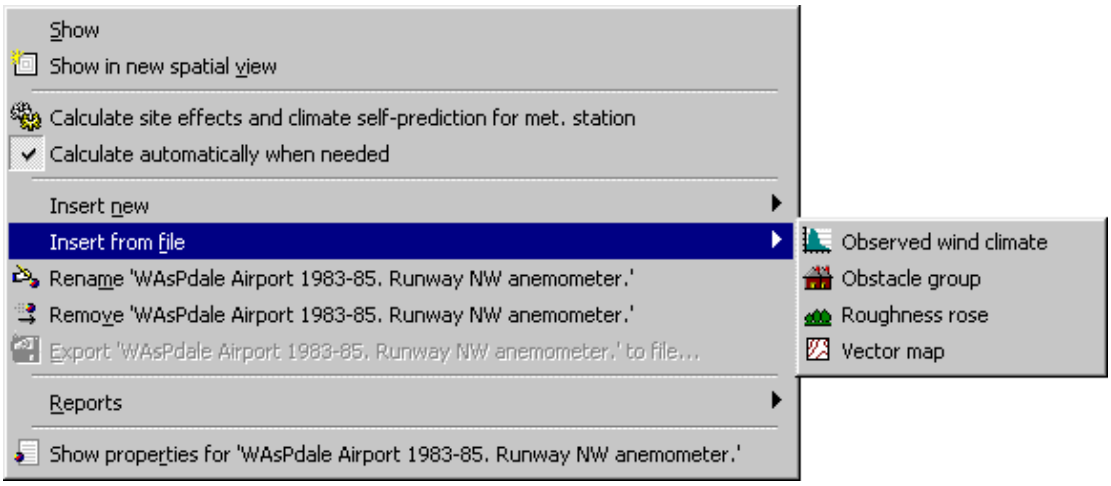
Any member which has its own user interface window will have a method called Show at the top of its menu. Clicking this will bring up the window in the window area on the right-hand side of the main window. It's possible to have several windows open at once and to leave them open while doing other work.

**Inserting members**

To insert a member to the workspace hierarchy

- Select the hierarchy member which will be the parent of the member to be inserted.

From the parent member's menu, select either Insert from file or Insert new. A secondary menu will appear, listing the types of hierarchy member which are legitimate children of the parent member. The 'from file' insertion menu looks like this (for a met. station):




Select the type of member to insert. If the Insert from file menu was used, then a file selection dialog box will appear. Select the file you wish to use to create the hierarchy member. If the Insert new menu was used, then the new member will be created immediately.

The new member will be added to the hierarchy as a child of the parent member.

**The member-specific insertion menus**

Depending on the type of parent member, the insertion sub-menus will contain different types of insertable member. Some members cannot be inserted as new members, and can only be inserted from file, so sometimes the Insert from file or Insert new sub-menus contain different lists.

Maps and wind turbine generators cannot be created or edited from within the WAsP application, so these types of member never appear on the Insert new sub-menu.

Although WAsP cannot create and edit observed wind climates directly, observed wind climates do appear on the 'insert new' menu for met. stations. When an observed wind climate hierarchy member is inserted as new, the OWC Wizard is automatically launched to guide you through the process of creating a new observed wind climate file.

**Inserting from the member methods toolbar**

Clicking on one of the two insertion buttons on the member methods toolbar also causes the a list of insertable member types to be displayed as a drop-down list.

**Inserting from the library**

An alternative way to insert members from file is to open and drag them from the library.

### 4.5.1 Moving members

Moving members from one place in the hierarchy to another is a simple matter of dragging with the mouse.

As the dragged hierarchy member is moved over potential 'target' parent members, the mouse pointer changes. If it would be impossible for the dragged member to be a child of the target, a 'no drop' icon is displayed, otherwise, the mouse pointer is the same as the hierarchy member being dragged.

 This is what the 'no-drop' icon looks like.

If a member is dropped onto a parent which cannot accept it, the move operation is not completed.

It is not possible to copy members by dragging them around the workspace: members can only be inserted, moved and removed.

### 4.5.2 Removing members

To remove a member from the hierarchy, simply select it and from its hierarchy member menu, choose  Remove. You can also highlight the member and press the Del key.

Removing a member from the workspace hierarchy does not cause the corresponding file to be deleted from the file system.

### 4.5.3 Saving members

Many hierarchy members can be saved or exported to file. When the workspace is saved, every member in the whole workspace is saved to the workspace file.

 To save or export a member's data, simply select it and from its hierarchy member menu, choose Export to file. You will be asked to provide a name for the file in a standard file selection dialogue window. This method is not available for workspaces, met. stations and turbine sites.

### 4.5.4 Members' properties

Many hierarchy members have a Properties method. If this method is invoked, a dialog is displayed which shows some of the properties of the member, particularly relating to how it relates to the workspace hierarchy and the underlying file system.

Here is an example for a wind atlas hierarchy member:


There's no information here which you actually need in order to do WAsP modelling, but it can sometimes be useful if the relationship between the hierarchy member and the files on the system is confused.

### 4.5.5 Refreshing the workspace hierarchy display

If a problem is encountered, then it's possible to force WAsP to refresh the workspace hierarchy display. To do this, select the workspace hierarchy and press the F5 key on the keyboard.

The workspace hierarchy can be collapsed to the project level by selecting the Collapse tree to project level method of the workspace root hierarchy member.

### 4.5.6 Function keys

A few keyboard function keys and key combinations are recognised by WAsP:

**F1** invokes context-sensitive help for the active window.

**F5** refreshes the workspace hierarchy and library displays.

**Del** deletes the highlighted item.

**Space bar** scrolls the selection of a highlighted item, e.g. through the sectors in the OWC or PWC displays.

**Ctrl-C** copies the contents of the active window to the Windows clipboard.

# 5 Modelling with WAsP

## 5.1 Introduction

This section of the help facility describes the topographical concepts used in WAsP modelling, as well as the different models of WAsP: the roughness model, the flow model, the shelter model and the wind farm model.

In general terms, accurate predictions using the WAsP program may be obtained (Bowen and Mortensen, 1996) provided:

- the reference site (meteorological station) and predicted site (wind turbine site or met. station) are subject to the same overall weather regime,
- the prevailing weather conditions are close to being neutrally stable,
- the reference wind data are reliable,
- the surrounding terrain (of both sites) is sufficiently gentle and smooth to ensure mostly attached flows, and
- the topographical model inputs are adequate and reliable.

This is the short version of the Modelling with WAsP section – read on in the electronic WAsP help facility!

# 6 Feedback and support

## 6.1 Reporting problems

If you have any problems using the WAsP software, please send an e-mail to waspsupport@risoe.dk. If you do not have e-mail, you may send a fax to the number given here.

### 6.1.1 Don't hesitate

Don't hesitate to send some feedback, even if you are not sure whether it is a bug, a suggestion or just a question. Information about any user difficulty is really valuable, even if they are not caused by program errors. Some users are shy making of bug reports because they wrongly assume that the error it is somehow 'their fault', because they don't fully understand the program. Please, don't hesitate to report a problem to us.

### 6.1.2 Before you contact us...

Before you contact us, please make sure that you have the latest version of WAsP and that your problem has not been dealt with already. So,

- **Check the bugs list and FAQ**

A list of known issues will be maintained at www.wasp.dk. You may also want to check the list of Frequently Asked Questions (FAQ) which will be maintained at the same address.

- **Check that you have the latest version**

The latest version of the WAsP program can be downloaded from www.wasp.dk in the form of an update file to the main installation on the CD-ROM.

### 6.1.3 Reporting problems

If you decide that your problem or suggestion has not been dealt with already, please follow the guidelines below:

- **Provide the version number**

Let us know which version of WAsP you are using (please provide the full version number). Please also mention which operating system and Internet Explorer versions you are running.

- **Tell us how to reproduce the error**

Before you report the problem, try to make it happen again. Include a description of how to reproduce the bug when you send the bug report.

- **Provide the program's own error description**

When WAsP shows you an error message, you can request details. When the details are showing, you can press the 'Copy' button to put a complete exception report onto the Windows system clipboard. Paste this into the e-mail you send.

- **Provide the file**

If the software is having problems with a particular file, then please send it (zipped) along with the description. If the file is bigger than 50 kb, then e-mail first so that we can arrange a more appropriate way of transferring the file.

- **Provide the whole project**

To fix a bug, it is sometimes helpful to be able to reproduce the situation you're describing. The easiest thing is to have the whole project. You can export the whole project to a directory on your computer, then zip it up and send it along with the feedback message. Again, if the resulting file is bigger than 50 kb, then send an e-mail first and we can arrange another way of transferring the file.

Related topics  Learn more...

## 6.2 Making suggestions

The future development of WAsP could depend on you! Even though we have many ideas ourselves for the future development of the WAsP program, its user interface and built-in models, we welcome very much your suggestions and requests for new features.

Which features to include and how to implement them depend strongly on the response we get from the WAsP users. Please e-mail or fax your comments and suggestions to the addresses given here.

## 6.3 Frequently Asked Questions (FAQ)

Beginning with the release of WAsP 6 we have established and will maintain this list of Frequently Asked Questions; regarding the use of WAsP and WAsP-related software. Unless otherwise stated, the Q&A's refer to the latest version of WAsP, even though most of the information may be valid for previous versions as well.

**How can I use Surfer to make a wind resource map of an area?**

Golden Software's Surfer program can read and utilize WAsP's wind farm (RSF) and resource grid files (WRG) directly. In the Grid menu of Surfer, choose Data and enter the name of the wind farm or resource grid file. You will then get the message "File type not recognised!". Choose 'ASCII Data (.TXT)' and press the 'Ok' button. You may then get the message "Surfer error: Current data columns do not contain 3 or more distinct XYZ points". Disregard this message and carry on, specifying the Data Columns used for the *X* and *Y* coordinates and the wind power density/power production: column B contains the *X* coordinate, column C the *Y* coordinate and column *H* the power density or power production. Surfer can now make a grid from the data in the usual way – and a map of the wind resource can be made.

You can also make Surfer recognize these file types by adding the following two lines to the file Surfer32.ini – in the [GS Worksheet Import Filters] section – using a text editor like Notepad:

```
WAsP Wind Farm=WSIDAT32.DLL;RSF;GSdata

WAsP Resource Grid=WSIDAT32.DLL;WRG;GSdata
```

**How can I generate a WAsP map from gridded data or spot heights?**

The Surfer program can make a contour map of an area from spot heights given in a regular grid; a so-called digital elevation model. The grid data may be input directly or it can be generated by Surfer from irregularly spaced spot heights. The Surfer program can further be employed to edit the map contents, e.g. the map limits and contour interval. The height contours of the map can be exported as a 3-D DXF-file from Surfer's Map menu (Contour Map/Export Contours). This DXF-file can be converted into a WAsP MAP-file by the WAsP Utility Program dxf2map.exe.

Gridded height data can also be transformed directly into a WAsP MAP-file using the WAsP Utility Program grd2map.exe. This program reads Surfer ASCII GRD-files and writes WAsP MAP-files. The vertical contour interval and elevation range for extracted contours may be specified by the user.

## 6.4 WAsP courses and training

The Wind Power Meteorology Program at Risø offers courses and training in wind resource assessment, site characterization, use of the WAsP software and application of the wind atlas methodology.

### 6.4.1 Standard WAsP course

Realistic assessment of the wind resource is a key parameter in any wind energy project – large or small. The course aims at providing practical experience and confidence in wind data analysis, wind climate estimation and power production calculations – using the WAsP program, a state-of-the art collection of PC tools developed specifically for these purposes.

The standard WAsP course is scheduled for 3 days and is held every year, at Risø or abroad. The number of participants is usually about 10 to 15 and we aim at providing one teacher for every five participants. An outline of the contents of the course and more detailed information is given in the Appendix section of this report.

### 6.4.2 Specific WAsP courses and training

In addition to the standard WAsP course, Risø offers courses and training tailored specifically to meet the needs of a particular institution, company or wind energy project. Such training is usually carried out at the premises of the client and may further include training in e.g. siting of wind-monitoring stations, met. station analysis, site characterization, and reporting of the wind resource assessment activities. Please contact Lars Landberg for more information and a quotation.

### 6.4.3 Project supervision and QA

For the experienced WAsP user, Risø can offer to review the data and results of any wind resource assessment project – whether wind atlas, wind resource map, wind farm production calculation, or tender document – in order to assure the quality of the work. This transfers the latest knowledge and further build the capacity of your company or institution. Please contact Lars Landberg for more information and a quotation.

## 6.5 WAsP Utility Programs

The WAsP Utility Programs is a collection of DOS (16/32-bit) and Windows (W95/98/Me/NT4/2k/XP) programs to calculate, analyze, convert, transform, translate, plot and print WAsP-related data. A brief description of each utility program is given below. Note, that a few utilities are now included in the WAsP package.

Registered users of the WAsP Utility Programs may download the latest update here.

### 6.5.1 Wind-climatological fingerprint

As in the European Wind Atlas. Fingerprint page with graphs (*.ps or *.plt file) and X-tables (*.txt or *.tex) of daily/yearly and monthly/yearly mean wind speeds.

### 6.5.2 Fitting Weibull distribution functions

Generates measured and fitted data (*.dat) for e.g. plotting the total and sector-wise wind speed distributions from an Observed Wind Climate file (*.tab). Summary table (*.txt or *.tex) in two different layouts. Conversion of any old WAsP-for-DOS *.tab-file format to the new standard WAsP-for-Windows format.

### 6.5.3 Plotting the histogram and wind rose

Generates data and Grapher files for plotting the wind speed and direction distributions. Data can be used with other plotting programs as well.

### 6.5.4 Weibull distribution characteristics

Statistics and data files (on screen and *.dat) for a given Weibull distribution (*A* and *k* parameters). Total power density and window (e.g. 0-25 $ms^{-1}$) power density. Power production from specified power curve. Data file suitable for plotting.

### 6.5.5 Plotting the obstacle set-up

Generates data and DOS Grapher files for plotting an obstacle set-up.

### 6.5.6 Coordinate transformation

Coordinate transformation (ED50 and WGS84) of single points, lists of points and WAsP ASCII *.map files:

- Latitude/longitude to UTM
- UTM to latitude/longitude
- UTM to UTM (zone 32 and 33 only)
- Un-scaling a WAsP ASCII map file to absolute coordinates
- Conversion of WAsP *.map file to *.bln and *.xyz files as well

### 6.5.7 Conversion of vector map formats

- AutoCAD *.dxf to WAsP *.map file (ASCII *.dxf-file subset only)
- Atlas *.bna to WAsP *.map file (Didger *.bna file)
- MapGen *.dat to WAsP *.map file (Coastline Extractor *.dat file)

### 6.5.8 Transformation of map and grid files

- Map to grid transformation: WAsP *.map file to Surfer *.grd file
- Grid to map transformation: Surfer *.grd file to WAsP *.map file

### 6.5.9 Ruggedness index (included in WAsP)

Calculates the ruggedness index (RIX value) for a single site or for multiple sites given in an RSF-file. Input is a WAsP map file. Results for site overall and for each sector.

### 6.5.10 Map editing (included in WAsP)

Map editing features like WAsP in a Windows environment (W95/98/NT). Roughness line analysis, e.g. joining these where they meet in node points and pointing out lines where the roughness values are in conflict. On-screen digitisation of scanned maps.

### 6.5.11 Interpolation of wind atlas data sets

Generation of an 'artificial' WAsP wind atlas data set (*.lib file) by spatial interpolation between three other stations/*.lib-files. This is a W95/98/NT utility program.

### 6.5.12 Plotting the power- and thrust-curves

Generates data and Grapher files for plotting the power-and $c_p$-curves. Data can be used with other plotting programs as well.

### 6.5.13 Resource- to grid-file conversion

Calculation of Surfer grid files containing Weibull *A*, Weibull *k*, mean wind speed, mean power density, terrain elevation, or power production. Grid may contain absolute or normalised values. Export to (*x, y, z*) file as well.

### 6.5.14 Air density calculator

Calculation of air density from the elevation/altitude and mean air temperature at the site.

### 6.5.15 Printing wind atlas files

Generates text or LaTeX file, resembling the right-hand-side pages of the European Wind Atlas, from a WAsP *.lib file.

### 6.5.16 PostScript BoundingBox

Finding the BoundingBox of encapsulated PostScript files (*.eps), e.g. Grapher and Surfer for DOS output files.

### 6.5.17 Sample station description

Proposal for a comprehensive, yet compact, standard description of a wind-measuring station, based on the outputs from WAsP and the Utility Programs.

### 6.5.18 Further information and ordering

More information can be obtained by contacting the WAsP team at Risø. You can place an order at the WAsP home page. Bug fixes and updates will be available for download from the WAsP home page.

## 6.6 WAsP Engineering

WAsP Engineering is a computer program for the estimation of extreme wind speeds, wind shears, wind profiles and turbulence in complex terrain. Version 1.0 was launched in July 2001 at the European Wind Energy Conference and Exhibition in Copenhagen; present version is 1.2.

The purpose of WAsP Engineering is to support the estimation of loads on wind turbines and other civil engineering structures situated in complex terrain. The wind properties that are treated are:

1. **Extreme wind speeds**, e.g. the 50-year wind. If a wind turbine is well situated on a hill the mean wind speed and thereby the power production can be increased significantly compared to that over flat terrain. Unfortunately, the 50-year wind will increase correspondingly, maybe calling for increased strength of the blades or other parts of the turbine.

2. **Wind shears and wind profiles**. Strong mean wind shears (large differences in the mean wind speed over the rotor) give large fluctuating loads and consequently fatigue on the wind turbine blades, because the blades move through areas of varying wind speed.

3. **Turbulence**. Turbulence (gusts of all sizes and shapes) causes dynamic loads on

various civil engineering structures, including wind turbines. The strength of the turbulence varies from place to place. Over land the turbulence is more intense than over the sea. Also the hills affect the structure of turbulence. We model various terrain dependent properties of turbulence.

Please visit the WAsP Engineering home page for more information.

## 6.7 The WAsP/KAMM method

The wind is simulated with the Karlsruhe Atmospheric Meso-scale Model KAMM using a large-scale climatology, e.g. from the NCEP/NCAR reanalysis data set. Wind atlas files are generated from the simulated winds. The wind atlas files can be read by WAsP to predict the very local wind climate using the local topography.

Please visit www.mesoscale.dk for more information.

## 6.8 Contacting the WAsP team

For general inquiries, sales support, shipping, invoicing etc. send an e-mail to wasp@risoe.dk.

For licence-related inquiries, send your dongle ID number to wasplicence@risoe.dk, quoting your user name.

If you have any problems using the WAsP software, please send an e-mail to waspsupport@risoe.dk. This way your problem and questions will be registered properly and distributed to the right person in the WAsP team.

E-mail: niels.g.mortensen@risoe.dk
ole.rathmann@risoe.dk
lisbeth.myllerup@risoe.dk
lars.landberg@risoe.dk

Web: http://www.wasp.dk

Fax: +45 46 77 59 70

Phone: +45 46 77 50 97 (Ms. Rikke Nielsen)

Post: Wind Energy Department

Risø National Laboratory, VEA-118

DK-4000 Roskilde, Denmark

# 7 Other information sources

## 7.1 European Wind Atlas

The European Wind Atlas was published in 1989 for the Commission of the European Communities by Risø National Laboratory. It is a hardback book of 656 pages with 16 colour maps and a data disk. The European Wind Atlas is:

- A data bank of European wind climate: it contains comprehensive wind statistics from more than 200 stations covering the entire EC (1989), plus colour maps of the wind resources of each EC country.
- A handbook for regional wind resource assessment and the local siting of wind turbines, including computational procedures for the effects of shelter, roughness and orography on power production.
- The basis for reliable estimates of the wind resources in the EC countries (1989), whether on a regional scale or at a specific site.

An overview map of the European wind resource based on the Atlas is given below.

### 7.1.1 Contents of the Atlas

The Atlas is divided into three parts, each intended for readers with different areas of interest – from laymen to professional meteorologists:

**Part 1**: The Wind Resource provides an overall view of the wind climate and magnitude and distribution of wind resources in the European Community countries. This part of the Atlas is intended to be useful to politicians, planners and laymen in general. The descriptions, figures, tables and colour maps permit a first, rapid identification of regions with favourable wind resources.

Contents of Part 1: The wind climate of Europe • Wind resource maps.

**Part 2**: Determining the Wind Resource gives explanations and information needed for the purpose of regional wind resource assessments and the local siting of wind turbines. In addition, it contains descriptions, raw statistics, and wind atlas statistics for 220 meteorological stations in the EC. It also includes methods for calculating the influence on the wind resource of various features in the landscape such as coastlines, forests, hills, and buildings.

Contents of Part 2: General concepts • The roughness of a terrain • Shelter behind obstacles • The effect of height variations in the terrain • Regional wind energy potential • Use of the wind resource maps • Siting • Selection of wind climatology for a site • Roughness classification • Calculation of statistics for a site • Calculation of shelter • Orography • Power production • Determination of mean power production • Power density function • Power duration curve • Optimisation of power production • Station statistics and climatologies • Station description • Raw data summary • Regional climatology and mean values • Windclimatological fingerprints • Station statistics and climatologies • Radiosonde statistics.

**Part 3**: The Models and the Analysis explains in detail the meteorological background for the Wind Atlas. It describes how the analysis was performed from the data and station information, and discusses the physical and statistical basis for the Wind Atlas models. The validity of the models and the analysis is demonstrated through a number of comparisons between measured and modelled wind statistics.

Contents of Part 3: The physical basis • Surface-layer similarity laws • The geostrophic drag law and the geostrophic wind • The stability model • The roughness change model •

The shelter model • The orographic model • The statistical basis • The Wind Atlas analysis model • The Wind Atlas application model • Meteorological data and station description • Radiosonde statistics • Limitations of data and models • Verification of the Wind Atlas methodology • Station intercomparisons • Validation against high meteorological masts • References • List of symbols • Auxiliary tables • Selection criteria and questionnaire • The data disk.

### 7.1.2 Non-English translations

The text of the Atlas has been translated into French, German, Italian, and Spanish. These translations contain the entire text of the Atlas as well as the statistical tables of the French, German, Italian, and Spanish stations, respectively. One non-English edition may be supplied free of charge when purchasing the English reference edition.

### 7.1.3 Application of the Atlas

The Atlas is the meteorological basis for estimating the wind climate and wind energy resources of any particular site in the EC. The application of the Atlas as a siting handbook is explained in detail in the Atlas.

To facilitate resource calculations and specific siting of wind turbines, the Wind Atlas is furnished with a disk containing all the regional statistics. The disk files can be used directly with the "Wind Atlas Analysis and Application Program" (WAsP), which was especially developed for the production of the Wind Atlas and for use in practical siting. The WAsP program is not included in the Atlas, but can be obtained from Risø National Laboratory.

### 7.1.4 Data disk

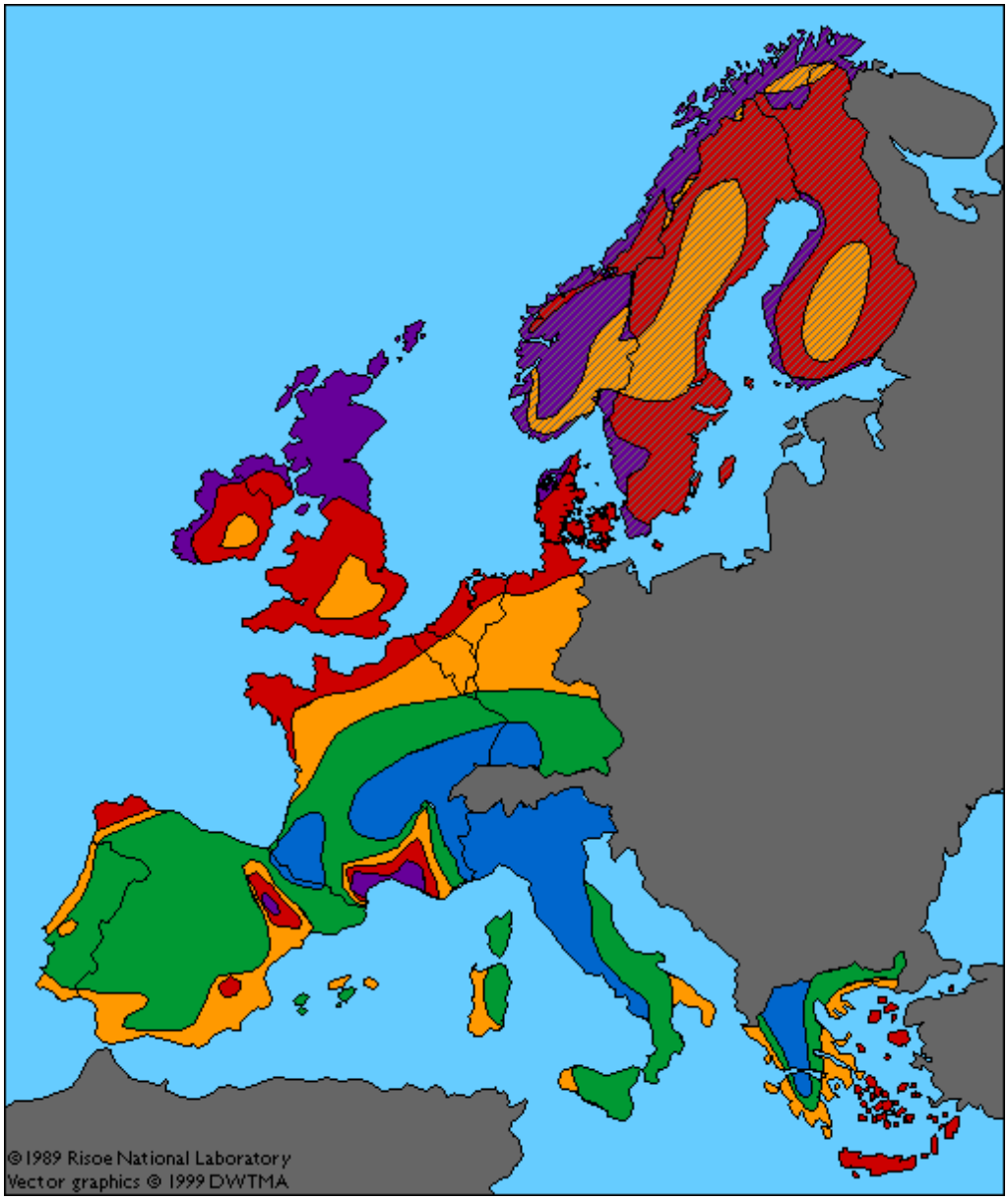
The observed and model-derived wind statistics from the 220 meteorological stations are furnished on a data disk together with the Atlas – for use with a PC or compatible computer. The data consists of the observed and modelled wind rose and wind speed distributions for each station.

### 7.1.5 From the Foreword

"The European Wind Atlas is a major outcome of the European Communities' overall effort to promote the market for electricity production from the wind resource in Europe and to develop the technologies and systems associated with it.

This Atlas completes the information previously published in several national wind atlases, and it will doubtless become an essential tool for all planners of wind energy applications in the Community. The data in this new European Atlas are far more comprehensive than those given in previous works. Moreover, this Atlas provides for the first time a coherent overview of all the EC countries, including the large regions with complex terrain. The latter was a major achievement because reliable computer codes had to be developed especially for this task...

I trust that all those interested in the future development of wind energy utilisation in Europe will appreciate this vast work and benefit from the comprehensive information it provides in their future activities." – Dr. W. Palz, Commission of the European Communities (DGXII)




| | m/s | W/m² | m/s | W/m² | m/s | W/m² | m/s | W/m² | m/s | W/m² |
|---|---|---|---|---|---|---|---|---|---|---|
| | >6.0 | >250 | >7.5 | >500 | >8.5 | >700 | >9.0 | >800 | >11.5 | >1800 |
| | 5.0-6.0 | 150-250 | 6.5-7.5 | 300-500 | 7.0-8.5 | 400-700 | 8.0-9.0 | 600-800 | 10.0-11.5 | 1200-1800 |
| | 4.5-5.0 | 100-150 | 5.5-6.5 | 200-300 | 6.0-7.0 | 250-400 | 7.0-8.0 | 400-600 | 8.5-10.0 | 700-1200 |
| | 3.5-4.5 | 50-100 | 4.5-5.5 | 100-200 | 5.0-6.0 | 150-250 | 5.5-7.0 | 200-400 | 7.0-8.5 | 400-700 |
| | <3.5 | <50 | <4.5 | <100 | <5.0 | <150 | <5.5 | <200 | <7.0 | <400 |
| | | | >7.5 | | | | | | | |
| | | | 5.5-7.5 | | | | | | | |
| | | | <5.5 | | | | | | | |

Vector graphics map by courtesy of the Danish Wind Turbine Manufacturers Association.

### 7.1.6 The reviewers wrote

"This book is a welcome attempt to quantify the meteorological aspects of the wind power available within the parts of Europe belonging to the European Community. The economic

viability of generating electricity from the wind is very dependent on not only the mean wind speed but also the distribution of the wind speed at a location. This book addresses this with an examination of 10 years' data from 220 meteorological stations across Europe." – K.L. Simms, *Weather* (1)

"The European Wind Atlas ... uses high quality surface wind observations as its primary data source. The key factor in the development of the atlas has been to transform the measured winds at specific sites into regionally representative values and climatologies. It is this step which sets this work apart from most other wind energy resource studies and has led to a consistent and reliable atlas...

Notwithstanding the weight, I strongly recommend the Atlas to all interested in wind energy and wind climatologies and, for other readers of Boundary-Layer Meteorology, I commend this as an example of the successful, well documented analysis of a complex micro-meteorological issue." – P. Taylor, *Boundary-Layer Meteorology* (2)

"While wind energy research in the United States starved from lack of funding during the last decade, progress continued in Europe. Denmark established a reputation for designing and manufacturing the world's finest modern wind turbines. The publication of the European Wind Atlas by the Risø Laboratory now confirms Denmark as a world leader in wind resource assessment as well... As the twentyfirst century approaches and the environmental wounds of fossil fuel consumption become more severe, wind and solar energy alternatives will certainly become more attractive. The European Wind Atlas is an important contribution toward the utilization of a major renewable energy resource. It is an essential reference for scientists and engineers involved with wind energy work in Europe as well as for serious students of Europe's climate. It can also serve world-wide as a guide for sophisticated wind energy resource assessment." – B. Martner, *Bulletin of the American Meteorological Society* (3)

(1) Weather is published by the Royal Meteorological Society. (2) Reprinted by permission of Kluwer Academic Publishers. (3) Reprinted by permission of the American Meteorological Society.

## 7.2 Wind Atlases of the World

The wind atlas methodology and the WAsP program has been applied in more than 80 countries and territories around the world for national, regional and local studies. A list of major national and regional studies – several of which contains WAsP data files on disk – is given below. The world according to WAsP is shown here.

### 7.2.1 Algeria

Hammouche, R. (1991). Atlas Vent de l'Algérie. In French. Office National de la Météorologie, Alger. 150 pp.

### 7.2.2 Australia

Dear, S.J., M.J. Bell and T.J. Lyons (1990). Western Australian Wind Atlas. Report No. 64, Minerals and Energy Research Institute of Western Australia, Perth. 28 pp. + 14 App.

### 7.2.3 Belgium

European Wind Atlas (1989), see Europe.

### 7.2.4 Brazil

Barbezier, G.L., E.A. Feitosa and J.S. Rohatgi (1999). Wind Atlas for the Northeast Region of Brazil. WANEB version 1.0. Brazilian Wind Energy Centre, Recife. 46 pp.

### 7.2.5 Denmark

Petersen, E.L., I. Troen, S. Frandsen and K. Hedegaard (1981). Wind atlas for Denmark. A rational method for wind energy siting. Risø-R-428. Risø National Laboratory, Roskilde. 229 pp.

European Wind Atlas (1989), see Europe.

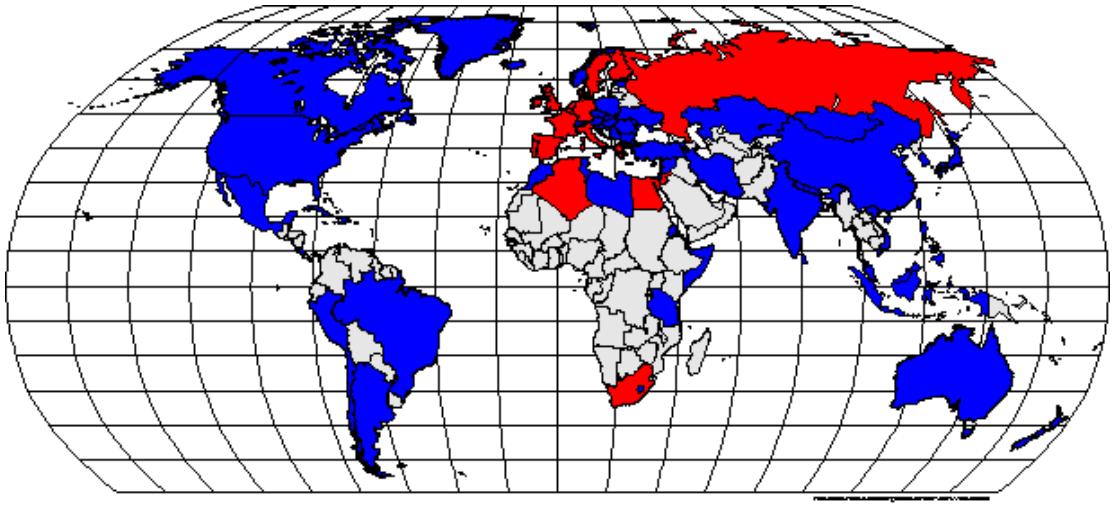
Mortensen, N.G., L. Landberg, O. Rathmann, G. Jensen and E.L. Petersen (1999). Wind Atlas Analysis of 24 Danish Stations (1987-96). In preparation for publication as Risø-R-1092(EN). Risø National Laboratory, Roskilde.

### 7.2.6 Egypt

Mortensen, N.G. and Usama Said Said (1996). Wind Atlas for the Gulf of Suez. Measurements and modeling 1991-95. ISBN 87-550-2143-3. Risø National Laboratory, Roskilde; New and Renewable Energy Authority, Cairo. 114 pp.

### 7.2.7 Europe

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 pp.



### 7.2.8 Finland

Tammelin, B. (1991). Suomen Tuuliatlas. Vind Atlas för Finland (Wind Atlas for Finland). In Finnish/Swedish. Finnish Meteorological Institute, Helsinki. 355 pp.

### 7.2.9 France

European Wind Atlas (1989), see Europe.

### 7.2.10 Germany

European Wind Atlas (1989), see Europe.

Traup, S. and B. Kruse (1996). Wind und Wind-energiepotentiale in Deutschland. Winddaten für Windenergienutzer. In German. Selbstverlag des Deutschen Wetterdienstes, Offenbach am Main. 445 pp.

### 7.2.11 Greece

European Wind Atlas (1989), see Europe.

### 7.2.12 Greenland

Mortensen, N.G. and L. Landberg (1993). Wind Energy in selected townships of Greenland: Qasigiannguit, Sisimiut and Narsaq. In Danish. Prepared for Nukissiorfiit/Greenland Power Company. Risø-I-718(DA). Risø National Laboratory, Roskilde. 37 pp.

### 7.2.13 Ireland

European Wind Atlas (1989), see Europe.

Watson, R. and L. Landberg (1999). The Irish Wind Atlas. University College Dublin, Dublin. In preparation.

### 7.2.14 Italy

European Wind Atlas (1989), see Europe.

### 7.2.15 Jordan

Højstrup, J. (1989). Wind Atlas for Jordan. Risø National Laboratory, Ministry of Energy and Mineral Resources, Jordan Electrical Authority, and Jordan Meteorological Department. 86 pp.

### 7.2.16 Luxembourg

European Wind Atlas (1989), see Europe.

### 7.2.17 The Netherlands

European Wind Atlas (1989), see Europe.

### 7.2.18 Portugal

European Wind Atlas (1989), see Europe.

### 7.2.19 Russia

Rathmann, O. (1998). Wind atlas analysis for 12 meteorological stations on the Kola Peninsula. Risø-I-1285(EN). Risø National Laboratory, Roskilde. 36 pp.

Starkov, A.N., L. Landberg, P.P. Bezroukikh and M.M. Borisenko (2000). Russian Wind Atlas. ISBN 5-7542-0067-6. Russian-Danish Institute for Energy Efficiency, Moscow; Risø National Laboratory, Roskilde. 551 pp.

### 7.2.20 South Africa

Diab, R. (1995). Wind Atlas of South Africa. Department of Mineral and Energy Affairs, Pretoria, 136 pp.

### 7.2.21 Spain

European Wind Atlas (1989), see Europe.

#### 7.2.22 Sweden

Krieg, R. (1992). Vindatlas för Sverige (Wind Atlas for Sweden). In Swedish. Slutrapport på projekt 506 269-2 på uppdrag av NUTEK. SMHI, Norrköping. 26 pp.

Krieg, R. (1999). Verifiering af beräknad vind-energiproduktion (Verification of estimated wind power productions). In Swedish. SMHI rapport Nr. 28, SMHI, Norrköping. 25 pp + appendices.

#### 7.2.23 United Kingdom

European Wind Atlas (1989), see Europe.

#### 7.2.24 United States of America

Artig, R. (1999). Minnesota Wind Resource Assessment Program. March 1999 report. Minnesota Department of Public Service, St. Paul. 157 pp.

## 7.3 Database on Wind Characteristics

This is a database of wind time-series intended primarily for wind (turbine) design purposes. Here you can find high-resolution (1-40 Hz) time-series, measured under different conditions at 55 different locations inside Europe, Egypt, Japan, Mexico and United States.

The database is compiled and maintained in Denmark by Kurt S. Hansen, Technical University of Denmark (DTU). The operation and maintenance is funded by Sweden, Norway, The Netherlands, United States and Denmark as an IEA Annex (XVII, operating agent Risø National Laboratory).

More than 162.600 hours of wind speed measurements representing 57 sites, 220 hours of structural wind turbine response measurements and more than 550.000 hours of wind resource measurements, representing 24 different sites with a maximum period of 14 years are available in the database. Further information is given in a folder and in the final project report, both of which may be downloaded from the Web-site.

Visitors are invited to browse through the wind statistics and view time-series (login as guest user). Registered users will obtain access to the advanced search facilities, download of wind statistics and time-series. Structural load measurements are also included in the database!

For further information on this database, please contact winddata@et.dtu.dk.

## 7.4 Risø readings in wind power meteorology

This is a list of selected papers, reports and published conference proceedings authored by or in collaboration with the staff of the Wind Power Meteorology Program of the Wind Energy Department.

### 7.4.1 Wind power meteorology in general

Petersen, E.L., N.G. Mortensen, L. Landberg, J. Højstrup and H.P. Frank (1998). Wind Power Meteorology. Part I: Climate and turbulence. Wind Energy 1, 2-22.

Petersen, E.L., N.G. Mortensen, L. Landberg, J. Højstrup and H.P. Frank (1998). Wind Power Meteorology. Part II: Siting and Models. Wind Energy 1, 55-72.

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 pp.

### 7.4.2 Wind measurements

Kristensen, L. (1998). Cup anemometer behavior in turbulent environments. J. Atmos. Ocean. Tecnol. 15, 5-17.

Kristensen, L. (1999). The perennial cup anemometer. Wind Energy 2, 59-75.

Mortensen, N.G. (1994). Wind measurements for wind energy applications – a review. Wind Energy Conversion 1994. Proceedings of the 16th British Wind Energy Association Conference, Stirling, June 15-17, 353-360.

Mortensen, N.G. (1994). Flow-response characteristics of the Kaijo Denki omni-directional sonic anemometer (DAT 300/TR-61B), Risø-R-704(EN), Risø National Laboratory, Roskilde, Denmark, 32 pp.

Mortensen, N.G., and J. Højstrup (1995). The Solent sonic – response and associated errors. Ninth Symposium on Meteorological Observations and Instrumentation, Charlotte, NC, March 27-31, 501-506.

### 7.4.3 WAsP and wind modelling

Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. Proceedings of the 1996 European Union Wind Energy Conference and Exhibition, Göteborg, Sweden, May 20-24, 584-587.

Frank, H.P. and L. Landberg (1997). Modelling the wind climate of Ireland. Boundary-Layer Meteorol. 85, 359-378.

Landberg, L. (2000). The mast on the house. Wind Energy 3, 113-119.

Mortensen, N.G. and E.L. Petersen (1998). Influence of topographical input data on the accuracy of wind flow modeling in complex terrain. Proceedings of the 1997 European Wind Energy Conference and Exhibition, Dublin, Ireland, October 6-9, 317-320.

Walmsley, J.L., I. Troen, D.P. Lalas and P.J. Mason (1990). Surface-layer flow in complex terrain: Comparison of models and full-scale observations. Boundary-Layer Meteorol. 52, 259-281.

### 7.4.4 Wind atlases

Mortensen, N.G. and Usama Said Said (1996). Wind Atlas for the Gulf of Suez. Measurements and modeling 1991-95. ISBN 87-550-2143-3. Risø National Laboratory, Roskilde, and New and Renewable Energy Authority, Cairo. 114 pp.

Mortensen, N.G., P. Nielsen, L. Landberg, O. Rathmann and M. Nielsen (1999). A detailed and verified wind resource atlas for Denmark. Proceedings of the Tenth International Conference on Wind Engineering, Copenhagen, Denmark, 21-24 June. 2013-2018.

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø

National Laboratory, Roskilde. 656 pp.

Petersen, E.L., I. Troen, S. Frandsen and K. Hedegaard (1981). Windatlas for Denmark. A rational method for wind energy siting, Risø-R-428, Risø National Laboratory, Roskilde, Denmark. 229 pp.

### 7.4.5 Short term prediction

Landberg, L., and S.J. Watson (1994). Short-term prediction of local wind conditions. Boundary-Layer Meteorol. 70, 171-195.

Landberg, L. (1999). Short-term prediction of the power production from wind farms. J. Wind Eng. Ind. Aerodyn. 80, 207-220.

## 7.5 On the Web

For general information about wind power, as well as links to other web sites related to wind power, a good place to start is www.windpower.org, the award-winning home page of the Danish Wind Turbine Manufacturers Association. A recent download of this entire home page is provided on the WAsP distribution disk.

### 7.5.1 Wind atlases, wind data and wind characteristics

For information on the wind climate of a particular country or region, you might check the list of wind atlases given here. The national or state meteorological service may also be able to help you; the national weather services are organised in the World Meteorological Organisation. For information on the detailed wind and turbulence characteristics of a given site or type of site, you might check the Database on Wind Characteristics.

### 7.5.2 Topographical and elevation data

The topographical information needed by WAsP consists of a roughness map and a height contour map. These digital maps are usually constructed by digitisation of ordinary, large-scale topographical (paper) maps. However, elevation and/or land-use information may already be available in digital form, in which case this information may be converted into WAsP-compatible maps. The national or state survey and cadastre should be able to help you find out whether such data exist.

**World coast lines**

The coastline is a very important elevation and roughness-change line; you can download the geographical coordinates of coastlines around the world using the Coastline Extractor. You can also download the coordinates of lakes, rivers and political boundaries from this site. An example of a map based on these data is given here.

**World elevation data**

Global elevation and land-cover data are also available over the Internet, e.g. from the Distributed Active Archive Center of the USGS EROS Data Center. The 'Global 30 Arc-Second Elevation Data Set' contains spot heights of node points in a grid with 30 arc-second resolution (926 m or smaller). These data are not detailed enough for WAsP flow modelling, but may be used for overview maps of a region or country; an example of such a map is given here.

### 7.5.3 Wind turbine and rotor blade manufacturers

For specific information on the characteristics of a particular wind turbine, you should contact the manufacturer directly. A list of major Danish wind turbine and rotor blade manufacturers is given below.

| Contact details | Internet home page | E-mail address |
|---|---|---|
| Bonus Energy A/S | www.bonus.dk | bonus@bonus.dk |
| NEG Micon A/S | www.neg-micon.dk | mail@neg-micon.dk |
| Nordex A/S | www.nordex.dk | nordex@nordex.dk |
| Norwin A/S | www.norwin.dk | norwin@mobilixnet.dk |
| Vestas Wind Systems A/S | www.vestas.dk | vestas@vestas.dk |
| Wincon West Wind A/S | www.wincon.dk | sale@wincon.dk |
| LM Glasfiber A/S | www.lm.dk | info@lm.dk |

The WAsP library contains wind turbine power and thrust curves from some of the manufacturers mentioned above.

## 7.6 References

The publications cited in this help facility are listed below.


Beljaars, A.C.M, J.L. Walmsley and P.A. Taylor (1987). A mixed spectral finite-difference model for neutrally stratified boundary-layer flow over roughness changes and topography. Boundary-Layer Meteorol. 38, 273-303.

Beyer, H.G., T. Pahlke, W. Schmidt, H.-P. Waldl and U. de Witt (1994). Wake effects in a linear wind farm. J. Wind Eng. Ind. Aerodyn. 51, 303-318.

Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. Proceedings of the 1996 European Union Wind Energy Conference, Göteborg, Sweden, May 20-24, 584-587.

Bowen, A.J. and N.G. Mortensen (1999). WAsP prediction errors due to site orography. Risø-R-995(EN). Risø National Laboratory, Roskilde. In preparation.

Charnock, H. (1955). Wind stress on a water surface. Quart. J. Roy. Meteor. Soc. 81, 639-640.

Jackson, P.S. and J.C.R. Hunt (1975). Turbulent wind flow over a low hill. Quart. J. Roy. Met. Soc. 101, 929-955.

Jensen, N.O. (1984). A Note on Wind Generator Interaction. Risø-M-2411, Risø National Laboratory, Roskilde. 16 p.

Jensen, N.O, E.L. Petersen and I. Troen (1984). Extrapolation of mean wind statistics with special regard to wind energy applications. World Meteorological Organization, WCP-86. 85 pp.

Katic, I. (1986). Wind conditions in wind farms (Vindforhold i mølleparker). In Danish. Risø-M-2582. Risø National Laboratory, Roskilde. 38 p.

Katic, I., J. Højstrup, and N.O. Jensen (1986). A Simple Model for Cluster Efficiency. Proceedings of EWEC'86 European Wind Energy Association, Conference and Exhibition, Rome, 7-9 October 1986. Eds. W. Palz and E. Sesto. Published by A. Raguzzi, Rome, Vol. I, 407-410.

Lettau, H. (1969). Note on aerodynamic roughness-parameter estimation on the basis of roughness-element distribution. J. Appl. Met. 8, 828-832.

Mortensen, N.G. and E.L. Petersen (1997). Influence of topographical input data on the accuracy of wind flow modelling in complex terrain. Proceedings of the 1997 European Wind Energy Conference, Dublin, Ireland, October 6-9, 317-320.

Perera, M.D. (1981). Shelter behind two-dimensional solid and porous fences. J. Wind Engin. and Industrial Aerodyn. 8, 93-104.

Petersen, E.L., I. Troen, S. Frandsen and K. Hedegaard (1981). Windatlas for Denmark. A rational method for wind energy siting. Risø-R-428. Risø National Laboratory, Denmark. 229 pp. Risø-R-428, 229 pp.

Petersen, E.L and I. Troen (1986a). Estimation of wind resources. In: Wind Energy in Denmark. Research and technological development. Ed. Fl. Øster. Published by the Danish Ministry of Energy, 29-36.

Petersen, E.L. and I. Troen (1986b). The European Wind Atlas. Proceedings of the European Wind Energy Association Conference and Exhibition, Rome, October 7-9, 1986, 191-200.

Rathmann, O., N.G. Mortensen, L. Landberg and A. Bowen (1996). Assessing the accuracy of WAsP in non-simple terrain. Wind Energy Conversion 1996. Proceedings of the 18th British Wind Energy Association Conference, Exeter, England, 25-27 September 1996, 413-418.

Rutkis, J. (1971). Tables on relative relief in middle and western Europe. University of Uppsala, Department of Physical Geography, UNGI Rapport 9. 21 pp.

Salmon J.R., A.J. Bowen, A.M. Hoff, R. Johnson, R.E. Mickle, P.A. Taylor, G. Tetzlaff and J.L. Walmsley (1987). The Askervein Hill Project: Mean wind variations at fixed height above ground. Boundary-Layer Meteorol. 43, 247-271.

Taylor, P.A., J.L. Walmsley and J.R. Salmon (1983). A simple model of neutrally stratified boundary-layer flow over real terrain incorporating wavenumber-dependent scaling. Boundary-Layer Meteorol. 26, 169-189.

Taylor, P.A. and H.W. Teunissen (1987). The Askervein Hill Project: Overview and background data. Boundary-Layer Meteorol. 39, 15-39.

Taylor, P.A. and J.R. Salmon (1993). A model for the correction of surface wind data for sheltering by upwind obstacles. J. Appl. Met. 32, 1683-1694.

Troen, I. (1990). A high resolution spectral model for flow in complex terrain. Ninth Symposium on Turbulence and Diffusion, Roskilde, April 30 - May 3, 1990, 417-420.

Troen, I. and E.L. Petersen (1989). European Wind Atlas. ISBN 87-550-1482-8. Risø National Laboratory, Roskilde. 656 p.

William-Olsson, W. (1974). A map of the relative relief of the western half of Europe, 1:4,000,000. Esselte Map Service, Stockholm.

Wood, N. (1995) The onset of separation in neutral, turbulent flow over hills. Boundary-Layer Meteorology 76, 137-164.

# 8 Appendices

## 8.1 WAsP forms

A number of sample forms are provided in the 'Forms' folder of the main WAsP directory. These forms may be used to record characteristics of the wind speed and direction data, the anemometer or wind turbine site, the meteorological station, the near-by obstacles, the surrounding roughness and for exchange of data storing units/cards on a met. station or for keeping a logbook. The forms are:

- Data Description Form
- Site Description Form
- Site Sketch Map
- Site Sector Photographs
- Station Description Form
- Obstacle Description Form
- Roughness Description Form
- Data Storing Unit Exchange Form
- Data Acquisition System Logbook
- Met. station inspection checklist

The Roughness Description Form is used for the site-specific roughness description or roughness rose. However, most often the roughnesses are specified in the form of roughness change lines in a map; to establish these a copy of the topographical map is most useful.

These forms should be considered as samples or templates; you may adapt each form to your specific needs. The Data Storing Unit Exchange Form was developed specifically for Aanderaa systems, but can easily be adapted to other systems/data-loggers.

## 8.2 Software

WAsP is a complete software package for wind data analysis, map editing, wind atlas generation, wind resource assessment and siting of wind turbines. Working with wind resource assessment and WAsP in practice, however, requires other software as well. In addition to a general-purpose office package containing a word-processor, a spreadsheet and a database, the software mentioned below may come in handy if you use WAsP on a regular basis.

**Text editor**

In order to create, view and edit the contents of text files you need a text editor. You can use Notepad to create or edit text files that do not require formatting and are smaller than 64K. Notepad opens and saves text in ASCII (text-only) format only. To create or edit files that require formatting or are larger than 64K, use WordPad. Both of these text editors are part of your Windows distribution.

**File compression software**

Some data and WAsP files – in particular the time-series wind data, the terrain map and the resource grid files – can get rather large in size. Software for file compression and archiving is therefore important, especially if you transfer files over the Internet or mail them on floppy disks. The WinZip package runs on most Windows platforms; an evaluation version is available from www.winzip.com.

**Digitising software**

The creation of a new map by digitisation of paper maps is not possible any more from within the WAsP program. Three possible workarounds are described here. We recommend the Didger program from Golden Software for digitisation of maps. The BNA output format from this simple and cheap digitising package can be imported directly by WAsP and the

new map editor utility. More information about this program is available from Golden Software. A demo version of the software is available here.

### Graphics and plotting software (2D)

The graphic displays of WAsP data, e.g. of the wind rose, speed distributions or the power curve, can be copied to the Windows clipboard and pasted into your printouts and reports. For even better quality graphics and publication-ready figures, however, you will need dedicated plotting and graphics software: the plotting routines of a spreadsheet program or, better yet, a scientific graphics software package like Grapher from Golden Software. A demo version of this software is available here.

### Graphics and plotting software (3D)

Many WAsP input data and results are spatial data: the contour and roughness maps, the wind farm layout and the wind resources over an area are important examples. It is of vital importance to be able to display these data and results in the best possible way, so it may be worthwhile to consider a plotting and graphics package specifically designed to illustrate spatial data. The Surfer package from Golden Software can make both 2D maps and 3D renderings of your WAsP data. A demo version of the software is available here.

### WAsP Utility Programs

The WAsP Utility Programs is a collection of DOS (16/32-bit) and Windows (W95/98/NT4) programs to calculate, analyze, convert, transform, translate, plot, and print WAsP-related data. A brief description of the main features of each utility program is given here. Note, that a few utilities have been included in the present WAsP package.

### WAsP Engineering

WAsP Engineering is a computer program for the estimation of extreme wind speeds, wind shears, wind profiles and turbulence in complex terrain. The purpose of WAsP Engineering is to support the estimation of loads on wind turbines and other civil engineering structures situated in complex terrain. Version 1.0 was launched in July 2001 at the European Wind Energy Conference and Exhibition in Copenhagen. A brief description with links is given here.

### Geomagnetism software

Terrestrial data available from the National Geophysical Data Center (NGDC) in Boulder, Colorado, and its collocated World Data Center, include the areas of topography, natural hazards, geomagnetism, gravity, global change, and other global phenomenon. Estimation of the values of the Earth's magnetic field – including the magnetic declination – can be done at the following NGDC web site:

Compute Values of Earth's Magnetic Field (Version 4.0)

The program run from this site computes the values of the Earth's magnetic field parameters for a given location and date, or date range. The inputs required are the date and location (latitude, longitude, and elevation) of interest. Elevation is especially important when computing the magnetic field at aircraft or higher altitudes. The form defaults to the current day.

### World Time software

The NIST (National Institute of Standards and Technology) Internet Time Service allows users to synchronize computer clocks via the Internet. The time information provided by the service is directly traceable to UTC (NIST). The service responds to time requests from any Internet client in several formats including the DAYTIME, TIME, and NTP protocols. Software and instructions may be downloaded from here.

AtomTime98 is a 32-bit Windows Internet (Winsock) application which will connect to the Atomic Clock time server in Boulder, Colorado (USA) and fetch the current atomic clock time value. It compares this value to your PC time and displays the difference (note, that Atomtime98 may not always guess the right time zone). You then have the option of updating your PC clock to match the atomic clock value. There are a number of options to

automate the update process. You may download AtomTime98 from here. Note, that AtomTime98 is a shareware application. After installing it, you have 30 days to evaluate the product. If you decide to keep AtomTime98, you are required to purchase a license key.

### 8.2.1 Hardware

Site visits to met. stations and wind turbine / wind farm sites are a valuable, and often absolutely necessary, part of wind resource assessment and siting work. For this, you need a 'real' toolbox...

**In the field**

For site visits you will at least need the following:

- Topographical maps (1:25,000 to 1:100,000). Maps should preferably show the topography at the time of the collection of the met. data, or be as recent as possible if you explore the wind resource for wind turbine site assessments. The contour line interval should be 20 m or smaller.

- Compass (360-degree). A good-quality, hand-held compass with divisions to the nearest degree. A sighting-type model is preferred for taking accurate bearings to nearby obstacles, for measuring boom directions, other bearings etc.

- GPS receiver (Global Positioning System). A battery-operated, hand-help GPS receiver should be preferred. Remember to use the datum setting corresponding to the map datum. If the map datum is not supported by the GPS, the World Geodetic System 1984 (WGS84) may be the best choice.

- Camera for taking photographs of the surroundings of the met. station and/or WTG position(s). Take sector-wise photographs from the site for each of twelve 30-degree sectors, as well as of the mast set-up, instruments and enclosure.

- Clinometer for measuring vertical angles (slope), e.g. in order to determine the height of instruments on the mast from the ground or to evaluate the steepness of near-by terrain slopes.

- Measuring tape. A measuring tape of about 25 m or more, to measure the distances to nearby obstacles and, preferably, the actual height of the wind measuring equipment (however, never enter a mast or tower without the proper safety equipment and procedures!)

- Summaries of wind measurements. Summaries of the wind speed and direction data from the met. station. Also, graphical presentations of the same: wind rose plot, wind speed histograms for each sector, etc. Similar information for predicted wind climates at WTG sites.

- WAsP forms and checklist. A number of sample forms are provided with the WAsP program. These may be used to record characteristics of the wind data, anemometer or wind turbine site, near-by obstacles and surrounding roughness.

- Pocket calculator, wrist-watch, notebook, pencil, eraser, spare batteries etc.

In addition, the following items may come in very handy, though they may not be absolutely essential:

- Binoculars

- Odometer or range-finder

- Vegetation or land-use maps

- Aerial photographs or satellite imagery

**In office**

In addition to your PC and a high-quality printer, you may consider:

- Digitising tablet (A3 or larger) for digitising the height contour and roughness change lines from standard paper map sheets. The tablet will require software to run it, e.g. Didger from Golden Software.

Scanner (flat-bed, A4 or larger) for scanning of background map images to be employed by the MapEdit program.

## 8.3 Golden Software demos

Golden Software's Windows-based demo software is fully-featured and you can use your own data to experiment with the software. However, the demos do not allow you to print, save, copy, cut, or export. The following demos are available on the WAsP CD-ROM, in the folder 'Golden Software':

**Surfer 8 Demo** (s8demo.exe: 12,432 KB): A powerful contouring, gridding, and surface mapping package for scientists and engineers. For Windows 98, Me, 2000 and XP and higher.

**Grapher 4 Demo** (g4demo.exe: 12,450 KB): Creates *(x,y)* graphs. An efficient and powerful graphing program. For Windows 98, Me, 2000 and XP and higher.

**MapViewer 5** Demo (mapvdemo.exe: 19,423 KB): Creates thematic maps. For Windows 98, Me, 2000 and XP and higher.

**Didger 3** Demo (d3demo.exe: 14,225 KB): Creates digital images from paper images. For Windows 95, 98, Me, NT4 SP3, 2000, XP and higher.

The demos may also be downloaded free of charge from Golden Software's download page. To view the entire Golden Software site, please visit www.goldensoftware.com.

### 8.3.1 Installation

To install a demo, click the Start button, then choose Run. Type the path and file name for the appropriate EXE file, or use the browse button to locate the EXE file. Press OK and setup will begin. Copyright © Golden Software, Inc.

## 8.4 WAsP course information

The 3-day course is intended for engineers, scientists and others, primarily working within the field of wind energy, who require a working knowledge of the WAsP program. Aspects of the theories underlying the program will be presented, but the course will stress practical experience and examples on the use of WAsP. Although the course requires no prior knowledge of meteorology or wind energy conversion technology, some familiarity with one of these areas, as well as basic knowledge of PC's, Windows and/or DOS would be advisable prerequisites.

### 8.4.1 Registration

Courses are announced on the WAsP home page. Binding registration must be received no later than two weeks before the course. Confirmation, practical details pertaining to the course in question and an invoice will subsequently be mailed by Risø.

### 8.4.2 Course fee

The course fee covers tuition, course materials and data, three lunches, one course dinner, light refreshments etc. Travel and accommodation are not included.

### 8.4.3 Presentation

The courses are presented by Lars Landberg, Niels Gylling Mortensen, Ole Rathmann and Lisbeth Myllerup from the Wind Energy Department at Risø National Laboratory. The language on all courses is English.

### 8.4.4 Hardware

Since practical experience is essential, the participant(s) from each company or institution should preferably bring their own notebook PC with the WAsP programs and User's Guide installed. Please advise us well ahead of the course, should this not be feasible.

### 8.4.5 Q & A session

The course will contain a Q & A session where questions raised by the participants will be answered. Questions or issues that you would like to be treated in this session, without reference to the person or company posing the question, can be mailed or faxed directly to Risø before the course.

### 8.4.6 Course programme

The following topics are covered during the standard 3-day WAsP course:

- Test of PC's and software
- Introduction & theory
- The WAsP program and User's Guide
- Terrain description and the Map Editor
- Terrain roughness and roughness change
- Shelter from buildings and natural obstacles
- Hills and flow modelling

- Complex terrain and other issues
- Analyses of meteorological data
- WAsP analysis: wind atlas generation
- WAsP application: wind resource prediction
- Wind power calculations and wind farms
- The WAsP Help Facility and other resources
- Case study – the participants carry out a complete WAsP analysis and application exercise
- Presentation and discussion of case study
- WAsP work in the field and in office: recommended hardware and software
- Q & A session
- Evaluation of course

# 9 Index

## B



## F



## H

**Bibliographic Data Sheet** **Risø-I-1950 (EN)**

Title and authors

Getting Started with WAsP 8

Niels G. Mortensen, Duncan N. Heathfield, Lisbeth Myllerup, Lars Landberg,
Ole Rathmann, Ib Troen and Erik L. Petersen

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Abstract (max. 2000 characters)

The Wind Atlas Analysis and Application Program (WAsP) is a PC-program for horizontal and vertical extrapolation of wind data. The program contains a complete set of models to calculate the effects on the wind of sheltering obstacles, surface roughness changes and terrain height variations. The analysis part consists of a transformation of an observed wind climate (speed and direction distributions) to a wind atlas data set. The wind atlas data set can subsequently be applied for estimation of the wind climate and wind power potential, as well as for siting of specific wind turbines. The WAsP 8 Help Facility includes a Quick Start Tutorial, a User's Guide and a Technical Reference. It further includes descriptions of the Observed Wind Climate Wizard, the WAsP Map Editor tool, the WAsP Turbine Editor tool and the Air Density Calculator.

Descriptors

COMPUTER PROGRAM DOCUMENTATION; DATA ANALYSIS; MAPS; RESOURCE ASSESSMENT; SITE CHARACTERIZATION; W CODES; WIND; WIND POWER.

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